Sandwell

FLOATING ICE - PANARCTIC

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: November 19, 1974

Ice Platform for Offshore Drilling Hecla N-52

INTRODUCTION

During the spring and summer of 1973, Foundation of Canada Engineering Corporation Limited (FENCO) designed an ice platform to be used by Panarctic Oils Ltd. in the Arctic Islands as an offshore drilling base. Prior to the design, a considerable amount of horizontal ice movement data had been collected by Panarctic. The natural ice at the well site, 8 miles offshore in Hecla and Griper Bay, was thickened by flooding and freezing in layers to provide an adequate support for the rig. Flooding began November 28, 1973, and was completed February 3, 1974. The Panarctic Tenn et al CS W Hecla N-52 well was spudded March 5 and the rig released April 15, 1974.

The results collected by us as a result of the monitoring during construction and drilling have been recorded and analysed exhaustively. Creep theory has been developed for the prediction of long-term deflections and stresses and ice buildup rates have been correlated to ambient temperature and wind. The elastic modulus for the ice was obtained for various depths and checked with surface values. Strength was also checked at different depths.

Design of the ice platform was based on the theory for elastic, homogeneous and isotropic plates of uniform section resting on an elastic foundation. Maximum extreme fibre stresses beneath the rig were calculated and were limited to between 25 and 30 psi, providing a safety factor against failure of around 6 in the uncracked state and 3 in the cracked state. The platform section tapered to the natural ice thickness at approximately 225 feet from the moon pool.

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Long-term deflections of the ice were estimated using a 1/30 reduced elastic modulus as it was desired to avoid flooding of the working area during drilling.

During construction and drilling, ice temperatures, total ice buildup, ice quality and vertical deflection measurements were taken. The results of these measurements and the subsequent analysis are outlined below.

1) Ice Buildup

The natural ice beneath the rig location was thickened to a maximum depth of 17.5 feet by flooding in thin layers with small pumps and allowing the layers to freeze before applying another lift. Between the beginning of December, 1973 and February 3, 1974, a maximum of 135 inches of ice was built up. The average buildup rate was 2.5 inches/day.

Statistical analysis showed a strong correlation between ambient temperature and buildup rates but none between wind velocity and buildup rates. It is felt that the adverse effects of wind on men and equipment offset any advantages gained from increased cooling of the flood water.

2) Vertical Deflection Measurements

Vertical deflections in the rig vicinity were measured frequently during drilling. As well, deflections were measured at fuel storage bladders placed on first-year sea ice at the aircraft turnaround area.

Total deflection next to the rig over a period of 40 days averaged 0.44 feet. Creep theory, developed from the basic creep power law, gave a total predicted deflection of 0.31 feet. However, this same theory showed good correlation with measurements taken at the bladders. Since the rig platform continued to deflect downwards after the start of rig down, it was felt that the ice had still not reached isostatic equilibrium after flooding. The small stresses introduced by the rig were not large enough to overshadow these other effects.

3) Ice Temperatures

Ice temperatures were monitored continuously during flooding. Because of the salinity of the built-up ice it had been decided to ensure that the built-up ice temperatures never exceeded -5° C so that the brine volume would be kept at an acceptable level. Ambient temperatures during flooding varied between -17°C and -47°C with an average of about -30°C. At the flooding rates experienced, no problem was encountered keeping built-up ice temperatures at or below -10°C.

Temperatures were monitored during drilling beneath the rig, the rig heater, and other buildings and excessive warming of the ice was not a problem. The two 2-inch layers of urethane insulation ($k=0.13$ Btu-in./hr.ft.^{2}F^o) and the 4-inch thickness of the wooden matting were effective in ensuring that ice temperatures did not exceed -5^o C.

4) Ice Salinity

Ice salinities in the natural ice were low, around 1 ppt, indicating multi-year ice beneath the rig platform. During construction and drilling, average salinities in the built-up ice were 15 ppt with peaks to 30 and 40 ppt. By the end of summer, approximately 4 feet had melted off the top of the platform and the average salinity of the remaining ice was 1 ppt.

5) Ice Strengths

Unconfined compressive strengths of the built-up ice near the surface varied between 600 psi and 1610 psi. Stress rates for these tests were between 600 and 1200 psi/min.

Confined compressive strengths near the surface averaged 2728 psi in the built-up ice.

The elastic modulus of the built-up ice near the surface was 580,000 psi and that of the natural ice averaged at 600,000 psi.

Borehole tests at various depths showed little variation in elastic modulus or strength. At 9.5 feet, the deepest test, a modulus of 450,000 psi was obtained.

6) Snow

Natural snow accumulation was not a problem. Specific gravities of naturally-deposited snow and of snow piled by machines were 0.5.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: July 9, 1975

East Drake I-55 Offshore Drilling Ice Platform

The platform was constructed by successive flooding and freezing of thin layers from electric submersible pumps at fixed locations. The electric pumps were a significant improvement over the gasoline screw-type pumps used previously at Hecla N-52 in terms of reliability, ease of operation and flow rates.

Vertical ice deflections were monitored by the use of optical levels and water level recorders. A deflection of 10 inches over a 50-day period left 18 inches of available freeboard at the conclusion of drilling.

A summary of the important factors in this project is given below.

Ice Buildup

The original natural ice thickness for pads 2 and 4 was 6.1 and 6.7 feet respectively on November 23, 1974. By flooding thin layers of 1 - 2 inches, an average buildup rate of 3.5 inches/day was achieved to give a final centre ice thickness of 16.3 feet for Pad 2 and 16.7 feet for Pad 4. There was no measurable natural growth in the centre pad areas thereafter. It is anticipated that, with improved working methods, a buildup rate of 4 inches/day can be realized for similar environmental conditions. In practice, winds over 10 mph reduce flooding efficiency.

Ice Temperatures

During flooding the temperature gradient of the ice sheet was monitored to prevent overheating. Flooding was resumed once the top foot of ice had reached a temperature of -5°C or lower. Once the platform was constructed, the temperature gradient became approximately linear from an average ambient -30°C at the surface to -1.7°C at the sea water interface. Temperatures remained stable in the ice platform during rig-up and drilling except in the moon-pool cribbing where there was a warming trend. It is recommended that the insulation be placed between the cribbing and ice in future projects.

Vertical Deflections

Measurements of the vertical movement of the ice sheet due to creep were made by optical survey and water level recordings. At the time of rig-up the available freeboard of 28 inches at Pad 2 was in excess of what would be expected from 16-foot thick ice. Therefore the platform behaved as if an effective load of 2,300,000 pounds was placed on it. A deflection of 10 inches in 50 days for this load is consistent in comparison to the deflection of 5 inches at Hecla N-52 where no excess freeboard existed. The long-term deflection of both I-55 and N-52 can be described by using an effective bulk elastic modulus of 30,000 psi in the deflection equations.

There was no measurable deflection of Pad 4 during the same period although there was an effective ice load due to excess freeboard. The comparative low stress produced by the distributed ice load resulted in a lower deflection rate.

The experience of N-52 and I-55 indicates that the allowable tensile stress used in the design can be increased to 70 psi and this increased design stress would be consistent with the limitations for long-term deflections. It is estimated that a factor of safety of 4 against failure exists whenever deflections are limited to the available freeboard.

The updated platform design for rigs No. 2 and 4 and the revised monitoring schedule are included as Appendix F and G to this report.

Ice Quality

Throughout the course of flooding and construction, the ice quality was determined from cores and strength tests. The ice cores taken from various locations in the pads showed the ice to be intact through the entire natural and built-up thickness with occasional high salinity pockets throughout the built-up thickness. Borehole tests confirmed that the strength of the built-up and natural ice decreases with depth or temperature but not to the degree that was previously assumed.

The average confined compressive strength of built-up and natural ice was calculated to be 3170 psi and 4210 psi respectively. Flaking tests gave corresponding values of 1205 psi and 570 psi for unconfined compressive strength.

Tides

Tides measurements gave a range of 40 inches vertical movement in the period January 2 to April 22, 1970.

The information gained from I-55 and previously at N-52 indicates that an ice platform is a feasible method for offshore drilling in areas of the high arctic where the horizontal ice movement is limited. The platform construction is essentially limited to the period November to February depending upon the available natural ice thickness in the fall.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: November 23, 1977

Offshore Drilling Ice Platforms for West-Hi Rig #1 at Drake F-76 and Roche Point I-43

The Marc CDC finite element program for short term load analysis and the Effective Modulus Equation for long term analysis were used to analyse stresses and deflections. Data from all previous platforms was extensively studied in order to produce a platform design which would limit deflections to available freeboard and short term maximum stresses to 70 psi.

The design of the two ice platforms is based on an available freeboard of 11% of the overall ice thickness. This particular value of 11% and more was found to be present at the Jackson Bay G16-A ice platform which is in many ways similar to the above two platforms. Additional information regarding the magnitude of the available freeboard can be obtained from Fenco's project report "Offshore Drilling Ice Platforms" submitted to Panarctic in July 1976.

In the additional amendment both platforms have been redesigned as a result of the recent changes in the rig weights and their durations. The locations of the weights remain the same, therefore, it seems reasonable to utilise the previous calculations plus the computer results as a basis for the redesign of the platforms.

The total weight on the Drake F-76 platform has been increased by 55 kips (1.5% of the total weight) resulting only in minor changes in deflections and stresses. The previously determined ice thicknesses remain unchanged. In the case of the Roche Point platform the total weight is reduced by more than 400 kips. This beneficial effect, however, has been taken up by an increase in the duration of some of the dead weights resulting in an increase in the long term deflections. For multi-year ice and the additional weights of tool shack and pipe storage a minimum ice thickness of 22 feet should be used for the Roche Point platform (see page 6 of the amendment).

We trust, for the given weights and their durations the most unfavourable cases have been investigated in both the original design as well as in the amendment.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: November 30, 1977

Drake Point Offshore Pipeline Near Shore Resistance to Ice Scour

Overview:

Fenco Consultants Ltd. were requested by Panarctic Oils Ltd. on October 11, 1977, to review a proposed system for protecting the Drake Point pipeline, to run from the F-76 offshore well to land, from scour by ice in the near shore regions. It had been proposed to pump a cold glycol-water solution through the annulus of a 24 inch pipe encasing the 18 inch conductor and thus to freeze a bulb of soil around the pipe from the 20 metre water depth to shore. The bulb of frozen soil would stiffen the pipe and presumably render it resistant to lateral and vertical ice forces from ice grounding in the shallower water.

Fenco were specifically asked to:

1) Review the effect of frost bulb growth with time.

2) Assess the danger of frost heave and buoyancy.

3) Examine several aspects of the soil capacity and reaction including but not limited to the following:

   a) Evaluation of the capacity of the pipe in conjunction with the frozen soil bulb to withstand normal and vertical forces from ice masses.

   b) Reaction of the unfrozen soil beneath

      i) the pipe and frozen soil bulb and
      ii) the 18" pipe bundle with no frost bulb protection.

   c) A prediction of ice lensing within the soil.

   d) Examination of soil-pipe composite interaction.

   e) Backfill recommendations.

4) Examine methods of monitoring the freezeback and pipeline reaction.

5) Chilling system design.

Fenco, in cooperation with its sister company, Geocon (1975) Ltd., has assessed the effectiveness of the frozen soil system according to the above outline with minor exceptions.

In addition to the above tasks, Geocon was asked to conduct a review of a proposed frost heave test program, to analyse results from a plow model test program and to review frozen soil strength data.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: November 30, 1977

Drake Point Offshore Pipeline Near Shore Resistance to Ice Scour

CONCLUSIONS

Ice Pack of the Area and Scour Possibility

Conclusions

Scour action by ice on the pipeline in the nearshore region is possible. Two basic types of scour action are considered possible.

The first type is by ice with 5 metres or less keel depth and this occurs every year.

The second is by ice 5 metres to about 20 metres keel depth. While scour at these depths is possible, the probability is unknown and is guessed to occur with a frequency of one in ten to one in one hundred years.

Sea Bottom Conditions - Geotechnical

Interpretation of provided data shows the sea bottom to be underlain by a very soft marine clay which is sensitive to disturbance. In the first 1.5 m (5.0 ft.) depth the water content of this clay is greater than the liquid limit and the clay has an undrained shear strength of 1.5 kN/m^2 (30 psf) which will decrease on remoulding. These shear strength values are very low resulting in settlement and sloughing of sea bottom under any construction activity.

Unconfined compression tests on frozen clay samples showed marked increase of the frozen shear strength with decrease of temperature. However, it should be noted that the frozen shear strengths were lower than for clays with fresh pore water. This can be explained by the salinity of the pore water.

Ice Forces and Action

Lateral scour action finds the pipe at its weakest and is the criteria for design of protection systems.

Wind stress in the ice pack is transferred to the buried pipe by thicker ice which is pushed by the pack and then scours the bottom.

Calculations based on limiting wind fetch and ice sheet internal stability showed that maximum concentrated ice forces of 3800 to 30,400 tonnes (8400 to 66,800 kips) are possible.

Maximum possible resistances of the bottom soil to scour are 4 to 10 times less than the corresponding ice forces. The soil cannot prevent scour.

There are limitations on scour depth as determined by the upward push of the soil on the shoreward side of the scouring ice mass. These limiting depths are far below the planned burial depth of the pipe and still allow maximum force application.

Stability against overturning of multi-year floes common to the area does not in general limit scour forces.

Thermal Analysis of Frozen Bulb

Freezeback calculations using one and two-dimension solutions from various sources for various pipe coolant temperatures (-10°C, -20°C, -40°C) show that about one year is required to grow frost bulbs of a diameter 3 to 4 times greater than that of the 24 inch pipe. Since freezing progresses as a root function of time, increasing the bulb beyond this diameter requires years of time.

Thawing of the frozen soil completely takes appreciably more time than freezing because the temperature differentials are lower, with heat transfer being to the soil at -2°C and the water at about -1°C. Years are required to completely thaw a metre or two of the bulb.

However, as pointed out under the geotechnical section, frozen soil strengths are highly temperature dependent and the frozen bulb strength is reduced to low values long before complete melting with subsequent loss of ability to resist ice scour action has occured.

Scour Resistance by the Pipe and Frozen Bulb System

The pipe and soil bulb were analysed as a beam on an elastic, perfectly plastic foundation subjected to small deflections and as a catenary subjected to large deflections. The beam analysis was for a cracked bulb surrounding a flexurally stiff pipe and an uncracked bulb surrounding a pipe with no flexural stiffness. Stiffness properties of the naked pipe and the frozen soil bulb were compared. The following conclusions are drawn.

FENCO CONSULTANTS LTD.
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REPORT DATE: November 30, 1977

Drake Point Offshore Pipeline Near Shore Resistance to Ice Scour

The pipe and/or soil bulb do not act as a catenary as large deflections are required for this which flexural strain limitations and geometry would not permit.

Comparison of pipe and frozen bulb section properties revealed that for frozen bulb diameters greater than 2.5 to 3.7 metres (8 to 12 feet) it is much stiffer and stronger than the naked pipe. Frozen soil tensile strength values of 138 to 345 kPa (20 to 50 psi) and elastic modulus values of 35 to 138 MPa (5,000 to 20,000 psi) were used in the analysis. Only frozen soil of -10^{o}C or colder was considered to contribute to the frozen bulb section strength.

Deflections of an uncracked soil bulb are much less than those of a cracked bulb and pipe at allowable stresses. Both systems had an elastic, perfectly plastic foundation. An uncracked bulb cracks before deflections large enough to exceed the foundation soil yield strength are reached.

A diagram comparing forces causing maximum allowable pipe and frozen soil beam deflections with maximum expected ice forces was presented. Uncracked, frozen soil bulbs of up to 40 feet in diameter, requiring some 20 years to grow, will not resist expected ice forces. The ice forces exceed the allowable forces by a factor of 10 or more.

Similarly, a flexurally stiff pipe surrounded by a cracked soil bulb will not come close to resisting ice scour forces. Both of the above systems are much stronger than a naked pipe but are not strong enough.

The pipe and frozen bulb system will not resist lateral scour forces from yearly expected ice any better than from the less frequent scouring ice of greater thickness. Little reduction in total ice force can be expected as one approaches nearer to shore and shallower water.

The ability of the frozen soil bulb and pipe system to resist vertical forces from the onshore movement of ice is marginal at best.

<u>Frost Heave and Buoyancy</u>

Estimates of frost heave of the proposed chilled pipelines indicate it to be in the range of 0.1 m (0.3 ft.) to 1.5 m (5.0 ft.) for an estimated 30 year lifespan of the operation. It is felt that the actual total frost heave will be closer to the lower value. Frost heave test results provided by Panarctic support this conclusion.

However, this frost heave may be compensated and even be exceeded by settlement of the frost bulb due to consolidation of the underlying soft clay. This is due to the fact that the freezing will break the hydrostatic condition at the frost front thereby increasing the weight within the frost bulb from submerged to total weight condition.

A review of buoyancy of the flowline during different stages of installation and operation show that a buoyant condition may develop only at one stage. This could occur during the dragging of the pipe along the trench through remoulded clay. If this clay was remoulded sufficiently enough that it acted as a fluid, the pipe would float within this remoulded clay.

Pipe Trench

Analysis of the designed trench geometry with about 1.4 m (4.5 ft.) depth indicates that the trench walls would be stable in subject sea bottom with undisturbed clay. The construction of the trench with the prepared plan will remould the clay under the action of the skids, plow and floating boards resulting in sloughing of the trench walls. It is believed that the trench may fill up to nearly half of its design depth. This conclusion is supported by model test studies carried out by R.J. Brown and Associates.

RECOMMENDATIONS

The following recommendations regarding placing of the pipe and protecting it from scour by ice in the near shore regions are made.

1. Since the pipe and bulb of frozen soil cannot resist expected ice scour forces, the concept of freezing soil around the pipe by circulating a cold fluid should be abandoned.

2. The pipe can be protected from ice scour at 5 metres water depth or less by constructing a berm of frozen material over it in this region using only natural freezing. The berm could consist largely of ice with a granular soil insulating blanket on top. The buoyancy of the ice would ensure that the weak soil beneath were not overloaded with resulting failure or large deflections.

   The berm could be constructed using standard ice platform construction techniques and could be instrumented with banks of thermistors for quality control during flooding and subsequent performance monitoring.

Ice forces would be transferred to the berm and thence to shore by compression or shear action. Freezing to bottom in the first year is not critical and would occur with time, adding to the already considerable strength of the system. The installed thermistors would quite effectively monitor this gradual freezeback.

Some maintenance at the front of the berm may be necessary from year to year but experience with similar structures indicates it should not be expensive. The granular insulating layer on top of the berm and the low average ambient temperatures will obviate the use of artificial freezing.

3. The pipe can be protected from ice scour in deeper water only by burying it to a depth of about 20 metres (Figure 4.5 of report). If this is not practical, then it is best to leave the pipe naked. As stated, the probability of scour in deeper water is not known but is less frequent than in 5 metre water and the chances of survival may be good. At any rate, the frozen soil bulb will not protect it.

4. It is recommended that the possibility of pulling the pipe right behind the plow be reviewed. Our understanding is that the present procedure will consist of first plowing a trench followed by pulling of the pipe through the trench. We believe that it will be difficult to install the pipe at the desired depth and possibly even in the desired pipe alignment because of the in filling of the trench by sloughed material, also the trench walls might not provide sufficient control to keep the pipe aligned within the trench.

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FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: September 4, 1978

Offshore Drilling Ice Platforms Roche Point O-43 and Cape Grassy I-34

Overview:

During the 1977-78 winter season, the drilling of three offshore wells from ice platforms brought the total of wells drilled by this method to ten. This report deals with the Cape Grassy I-34 and Roche Point O-43 ice platforms. Previous offshore wells completed by this method were Hecla N-52, Drake I-55, Hecla P-62, Hecla M-25, Jackson Bay G-16A, Drake P-40, and Hecla C-58.

The fact that Rig #2 has drilled from a first-year ice platform is an important occurrence because the data collected will allow a comparison of first-year ice and multi-year ice platform behaviour. The six previous Rig #2 ice platforms were all multi-year ice platforms. Also the drilling of Roche O-43 with Adeco Rig #4 on a multi-year ice platform will allow a further first-year and multi-year comparison because Adeco Rig #4 drilled Jackson Bay G-16 on a first-year ice platform.

Operation Schedule:

Site	Start Flooding	Complete Flooding	Initial Thickness	Final Thickness	Start of Rig-Up	Spud Date	Release Date
Cape Grassy I-34 (Pad 2)	Dec 2	Jan 27	2.9'	17.0'	Feb 14	Mar 11 Mar 3	Apr 18
Roche Point O-43 (Pad 4)	Nov 10	Dec 28	6.4'	17.6'	Dec 28	Jan 18	Apr 18

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: September 29, 1978

Offshore Drilling Ice Platform Drake F-76

Overview:

In the winter season of 1977-78 a sea ice platform was constructed at Drake F-76 to allow West-Hi Rig #1 to drill and complete a production well. In the design of the platform, parameters were used which were taken from the performance of former ice platforms. This report studies the behaviour of the ice platforms of Drake F-76 in terms of measurements obtained during the operation of the Rig #1 and the results are compared with predicted design data.

The total depth of the well was approximately 1128 m (3700 ft) and the maximum total load applied to the ice platform was about 3800 kips. Starting on a 1.03 m (3.4 ft) ice thickness of first-year ice, the ice platform was built up by flooding and freezing the surface to a final average thickness of 7.10 m (23.3 ft) at January 26 1978.

Construction Operation Dates:

Start Flooding:	**Nov. 14, 1977**
Completed Flooding:	**Jan. 26, 1978**
Initial Thickness:	**3.4 ft.**
Final Thickness:	**23.3 ft.**
Start of Rig-Up:	**Feb. 4, 1978**
Spud Date:	**Mar. 2, 1978**
Release Date:	**Apr. 28, 1978**

A first at this site was the collection of high quality strain data at five different levels in the ice platform at one station. This data allowed a strain profile to be calculated and very interesting and important observations were made from the results.

This report presents field data collected, studies platform performance and gives future recommendations.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: August 16, 1979

Offshore Drilling Ice Platforms W. Hecla P-62, NW Hecla M-25, Jackson Bay G-16 & 16A

Overview:

During the winter drilling season of 1973-74 Panarctic Oils Ltd. demonstrated the feasibility of sea ice platforms for arctic offshore drilling when they successfully tested the well at N-52. Another well was drilled at Drake I-55 during 1974-75 and this year three offshore wells brought the total to five.

There were a number of interesting "firsts" to this year's wells which further defined the limitations of ice platforms. For the first time two holes were drilled by Commonwealth Hi Tower Rig No. 2 at P-62 and M-25 during the same winter season. The thinnest pad was 14.7 feet at P-62 and it appears that even thinner ice can be used in future pads.

SITE	START FLOOD	COMPL FLOOD	INITIAL THICKNESS	FINAL THICKNESS	START RIG-UP	RIG RELEASE
G-16	14 NOV 75	7 JAN 76	3.9 ft	18.0 ft	11 JAN 76	27 APR 76
P-62	22 NOV 75	20 DEC 75	6.1 ft	14.7 ft	22 DEC 75	27 FEB 76
M-25	10 JAN 76	12 FEB 76	8.0 ft	16.3 ft	1 MAR 76	17 APR 76

The heavier Adeco Rig No. 4 was initiated at Jackson Bay G16 and remained on the ice for over 100 days. Ice movement necessitated respudding and therefore a thorough study should be made into means of staying over the hole when large ice movements occur.

The purpose of this report is to present and discuss the data gathered, analyze the platform performance and to make recommendations for future improvements.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: September 21, 1979

Study to Improve Method of Construction of Ice Platform for West-Hi Rig No. 1

Overview:

A number of contractors, chemical specialists, equipment manufacturers, etc. were contacted to determine the feasibility of operating the systems which were considered. Where systems were judged to show potential a detailed analysis was completed to determine the structural performance.

In total 7 methods as listed were studied:

(1) Foam cells frozen into the ice platform
(2) Snow pad on partially completed ice platform
(3) Air filled bladders on the bottom of the ice platform
(4) Empty fuel drums frozen into the ice platform
(5) Fans to create high winds over the ice platform
(6) Rotating irrigation system flooding
(7) Reinforcement in tension zone of the ice platform

Upon completion of an individual analysis of each system all the systems were ranked in order of how effectively we felt they would improve the construction of the ice platform. Reduction in time of construction and structural performance were the most important factors considered. Secondary factors in ranking the systems were cost, ease of installation, and possible future improvements. We felt that a system should be given greater merit if there is potential in the method to further reduce time of construction through expanded use.

(1) Foam Cells Frozen Into the Ice Platform: we recommend that this system be considered at present as the most feasible and practical method to improve the construction of the Rig 1 ice platform. A detailed study determined that a rigid pour-in-place urethane foam 1SO-100 Resin 22-1 which is marketed by C.I.L. be considered for ice platform construction. This material is a flammable foam which can be disposed of through burning. The design presented for Hazen F-54 produces a reduction in ice thickness of 1.1 m through use of a 500 tonne buoyancy system which represents 14 days of flooding. The distinct advantage of this system over the fuel bladders would be that they could be installed during the construction period and consequently no time would be lost for installation. Also in the future increased amounts of foam could be employed to further reduce required ice thickness.

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Study to Improve Method of Construction of Ice Platform for West-Hi Rig No. 1

(2) Air Filled Bladders on the Bottom of the Ice Platform: we recommend that this system be considered as a feasible method. Calculations show that at Hazen F-54 a reduction in ice thickness of 1.1 m could be achieved through use of a 500 tonne buoyancy system. This represents 14 days of flooding and will significantly add to the time to complete the well to total depth. The only drawback to this system would be that about 4 days would be required to install the equipment after the moonpool is excavated. During this period we anticipate that the rig-up operation shall have to come to a near stop.

(3) Rotating Irrigation System Flooding: we recommend that this system should be considered as a feasible method. Calculations show that a buildup rate of 144 mm/day could be possible with this system under good weather conditions. Experience, however, has shown that this system is prone to breakdown and the actual buildup rates are not much higher than the conventional free flooding methods. It is conceivable that given properly designed and maintained equipment, significantly higher flooding rates could be achieved.

(4) Snow Pad on Partially Completed Ice Platform: we recommend that this system not be considered due to the small amount of time which would be saved (3 to 4 days) on platform construction.

(5) Reinforcing in Tension Zone of the Ice Platform: we recommend that this method not be considered at present until experiments are carried out to determine design parameters. Also at present it appears that a considerable cross-sectional area of steel in the order of .028 m^2 per metre of ice platform would be required. Also this method could only be employed on first-year ice due to the fact that reinforcement must be near the bottom of the platform.

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Study to Improve Method of Construction of Ice Platform for West-Hi Rig No. 1

(6) Fans: we recommend that this system not be considered due to the small amount of time (2 to 5 days) which would be saved in construction. The inconvenience and dangers to personnel of such a system also are of concern should the method be employed.

(7) Fuel Drums Frozen Into Ice Platform: we recommend that this method not be considered. The difficulty in transporting and installing such a large number of barrels would be insurmountable.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 10, 1979

Offshore Drilling Ice Platform Hazen Strait F-54

Overview:

The drilling Hazen F-54 occurred over the past winter season of 1978-79. The presence of thick multi-year ice through the Hazen area and a concentrated flooding schedule allowed for an early completion of the ice platform. Significant dates of construction and drilling follow:

Start Flooding:	**Nov. 19, 1978**
Complete Flooding:	**Jan. 20, 1979**
Initial Thickness:	**2.09 m**
Final Thickness:	**6.54 m**
Start of Rig-Up:	**Jan. 21, 1979**
Spud Date:	**Feb. 4, 1979**
Release Date:	**May 19, 1979**

CONCLUSIONS AND RECOMMENDATIONS

The Hazen F-54 ice platform was completed at an early date of January 20 through an intense flooding schedule and an early start-up date of November 19.

Studying the loads present showed that the long term load was 1303.6 tonnes. It was decided that the 148.8 tonne casing storage load should be classed as a short term load because this load was never present for longer than about 5 days.

Upon completion of the ice platform borehole jack tests on January 20 showed an average ultimate strength of 11.3 MPa for 39 tests done in built-up ice with an average calculated E_0 value of 359 MPa. Both of these values are lower than the values recorded at Drake F-76 which can be attributed to the heavy flooding schedule at Hazen and the presence of multi-year ice which has served to trap the brine in the built-up ice. Also it was found that as the season progressed the strength parameters increased considerably as drilling proceeded. This indicates that a heavy flooding schedule may cause lower initial strength parameters but this is not of concern because the platform will strengthen as cooling is allowed to occur.

The operation of the tide station showed a total tide range of 100 cm and no problems were experienced with the mechanical operation of the system.

The measurement of long term deflection was accomplished through use of a float recorder and a level surveying system. Both methods functioned very well but start-up was about 7 days late in both cases. A total deflection of 440 mm was recorded over the period of drilling. In the future the start-up date of at least one of the systems has to be before the start of rig-up date. Also the level survey shall be tied into the float recorder in the tide shack for a double check on the recorded elevations.

Temperatures recorded under Rig 1 during the drilling period showed a very stable safe temperature range in the ice platform. Circulation of water in the moonpool and the refrigeration system served to keep the moonpool area well frozen.

The strain gauge installation at Hazen was a success and very useful data was collected. The time versus maximum principal strain showed a direct relationship with the deflection versus time plot. This fact is an important consideration in platform design.

A study of long term deflection results showed that the following equation best fits all available Rig 1, Rig 2 and Rig 4 data.

$$W_2 = W_1 \left(\frac{P_2}{P_1}\right)^{1.8} \left(\frac{h_1}{h_2}\right)^{3.0} I_f$$

In order to reduce the amount of time required to construct the ice platform it is recommended that an artificial buoyancy system be used. Neth and Strandberg (1978) presented a number of possible devices which could be employed. The most feasible appears to be urethane foam cells which would provide 500 tonne uplift and reduce the design thickness by 1.1 m. At an average built-up rate of .074 m per day this represents 15 days of flooding.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 15, 1979

Offshore Drilling Ice Platform Whitefish H-63

Overview:

The thick multi-year ice present over the past winter season throughout the Whitefish area was of sufficient thickness to support Rig 4 with only limited flooding being required to level the platform area. The operation of Rig 4 at Whitefish H-63 adds an important area of data to ice platform theory. It will be possible to compare the long term deflection of a totally multi-year ice platform with a built-up ice platform. Also the degree to which tapered section affects long term deflection can be estimated.

Construction of the airstrip and lease road and transportation of the rig over the rough ice area presented considerable problems but a start of rig-up date of January 24 was still achieved.

SITE	START FLOODING	PAD 4 PROFILED	INITIAL THICKNESS	FINAL THICKNESS	START OF RIG-UP	SPUD DATE	RELEASE DATE
Whitefish H-63	Dec. 2/78	Dec. 17/78	6.26 m	6.36 m	Jan. 24	Feb. 18	May 21

CONCLUSIONS AND RECOMMENDATIONS

The Whitefish H-63 area was covered with extremely thick multi-year ice in the order of 6 m thickness. For this reason flooding with the submersible pump system was not required and flooding to level the lease was completed with the mobile pump units (Imps).

The January 24, 1979 start date for rig-up reflects the inavailability of Adeco Rig 4 which was drilling on a land location. The ice platform and airstrip were ready for the drilling rig on December 17, 1978, however, the first rig loads were not made available until January 7, 1979.

In previous years, Rig 4 had drilled offshore holes at Jackson Bay G-16A and Roche O-43 with start of rig-up of January 11 and December 28, respectively.

The borehole jack test as completed on December 18 and March 17 showed average ultimate confined borehole strengths of 21.6 MPa and 21.1 MPa, respectively. These values are typical for multi-year ice and indicated that the platform was comprised of sound ice.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 15, 1979

Offshore Drilling Ice Platform Whitefish H-63
The measurement of temperatures in the moonpool area showed that the ice in this area was maintained well below the freezing point throughout the drilling period. The start-up of the refrigeration system on February 8 prior to the spud date and circulation of water out of the moonpool ensured that melting did not occur. A study of long term deflection at Whitefish showed that the long term deflection was higher than expected.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 30, 1979

Drake Point Offshore Pipeline Ice Berm for Near Shore Scour Protection

On April 23, 1978 Panarctic Oils Ltd. completed its Drake F-76 gas well off the Sabine Peninsula of Melville Island in the High Arctic. Six days later gas flowed to shore by a marine flowline and a test program was started to evaluate the performance of the well-flowline and a test program was started to evaluate the performance of the well-flowline combination. This was the culmination of a two year engineering and construction program to demonstrate the feasibility of drilling such a well offshore in the Arctic, of completing it with a subsea wellhead and of connecting it to a marine flowline to onshore process facilities. This report is concerned with the design, construction and performance of the near-shore flowline protection system developed by FENCO CONSULTANTS LTD. and R.J. Brown Associates, to resist potential ice scour of the pipeline.

SUMMARY AND CONCLUSIONS

To protect the Panarctic Oils Ltd. Drake Point pipeline from ice scour damage in the near shore regions, a berm of grounded ice was designed and constructed during the winter of 1977/78. The natural ice from shore to the 5 m water depth was thickened by freezing and flooding in thin layers until the ice grounded. A 1 m layer of granular material was placed on top to protect the ice from thermal degradation. The design, construction, instrumentation and performance of this permanent facility are summarized below.

Cold fluid was also pumped through the annulus of a 610 mm pipe surrounding the 457 mm conductor to freeze soil around the pipe in an attempt to stiffen the system. The result of this program are described as well.

Berm Design

Ice and Soil Conditions

The ice in the Drake area is usually a mixture of multi-year and first-year ice, with the multi-year ice usually comprising 5/10 to 9/10 of the cover. Average thicknesses of 2.6 and 3.6 m and maximum thicknesses of 8.5 and 17.4 m were reported from ice thickness surveys.

Wind stress is the main driving force of the ice pack. Sustained wind velocities are often high and fetches large and maximum ice forces are often limited by the thickness, strength and stability of the ice sheet.

The Drake F-76 site is underlain by thick deltaic-marine deposits consisting of a highly plastic silty clay with occasional low to medium plastic clays and silt lenses with traces of sand. The marine clay exists both as unfrozen soil and as permafrost. The unfrozen clay has a high moisture content (approximately 70% near the surface) and as a result is in a semi-fluid state with shear strengths of 1.5 to 4.8 kPa. As a result it is a material incapable of supporting a buried pipeline against lateral or vertical push by scouring ice masses.

Berm Purpose

Scour by ice thickness of 5 m or less is considered to be possible frequently on the basis of data gathered from ice thickness surveys. Thus the ice berm extends from the 5 m water depth to the frozen shore and acts as a bumper, transmitting forces from its front to the frozen shore material. It also acts as a stiff matt and increases the weak soils ability to carry loads, such as the berms granular cover.

Ice Forces, Berm Stresses and Dimensions

The initial forces are those applied to the berm parallel to shore as they cause flexural tension at shore which could result in failure. The design of the as-built berm is summarized thus:

Allowable flexural stress (at shore)	500 kN/cm^2
Allowable shear stress (at shore)	500 kN/cm^2
Long-term ice load parallel to shore	38000 kN
Short-term ice load parallel to shore	136500 kN
Ice thickness at shore	2.13 m
Length of shear failure zone	152 m
Width of berm at seaward edge	150 m
Width of berm at shore	195 m
Factor of safety for shear - long-term	11.1
Factor of safety for shear - short-term	3.1
Factor of safety for flexure - long-term	3.8
Factor of safety for flexure - short-term	1.1

Berm Construction

Construction of the berm began in January, 1978, and ended in April, 1978. Initial ice thickness were about 2 m where the ice was not grounded. Small tracked vehicles with portable pumps were used in the initial stages and later electric submersible pumps were installed seaward of the berm. Fire nozzles were attached and water was shot onto the berm.

Initially, flooding only proceded on the east and west sides of the berm so pipe laying operations would not be interfered with. At no time were the flooding operation or flexural cracks at the edges a threat to the pipe laying operation.

Waste material from the pipe trench and ice blocks were flooded into the berm and reduced considerably the amount of flooding necessary. On April 8, flooding was completed, the berm was grounded and the placing of a 1 m cover of granular material began.

Monitoring of the Berm and Pipeline

Strings of thermistors were installed in the ice and soil of the berm and in the soil around the pipeline so that temperatures could be monitored and performance of the berm and the pipeline soil bulb freezing system monitored. Readings were taken 13 times between May 1, 1978 and March 10, 1979.

A Nikon F2AS camera was mounted on a tower near shore on the pipe centreline and kept a continuous photographic record of ice action and berm performance. The camera was in operation between June 27 and November 11, 1978, taking photos at intervals of 2 to 6 hours.

Performance of Berm

The berm successfully weathered its critical first year in operation. No thermal degradation of the ice in the bulk of the berm occurred and temperatures in the ice remained well below freezing, the active layer being confined to the granular cover. It is interesting to note that 2 m melted off the top of the ice drilling platforms over the wellhead. Deterioration was limited to 10 percent of the surface area. Principal areas where thawing and/or breaking away occurred were in the plow-hole area on the north edge and the north-east and east perimeter. Failure occurred in these areas since proper grounding of the berm could not be acheived. The plow-hole area had to remain open until the pipeline was in place and time did not submit grounding here. Along the perimeter, the natural ice sheet prohibited the edges of the berm from grounding and subsequent melting of the local ice freed these sections.

The photo monitoring of the berm and local ice conditions showed that no large floes came in contact with the berm. The local ice sheet did not completely thaw and open water conditions occurred in the near shore region. A number of small floes drifted harmlessly parallel to the north edge of the berm.

The progressive deterioration of the north edge of the berm was also captured on the photographs. Second year local failures of the berm are expected to be minimal.

Wave erosion of the berm ice at the waterline was also noted. During the winter this largely froze back. This type of erosion may come to equilibrium with restoration of summer eroded material during the winter.

Performance of Pipeline Refrigeration System

The pipeline refrigeration system performed to specification while in operation producing a frost bulb extending approximately 2 m around the pipe. Shut down of the plant on October 3 allowed the frost bulb to warm to a semi-frozen state by March, 1979.

RECOMMENDATION

Based on experience gained and measurements taken during the last year, the following recommendations are made.

Temperature monitoring of the berm and pipeline should continue through a second year. Photographic monitoring should also be continued.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 30, 1979

Drake Point Offshore Pipeline Ice Berm for Near Shore Scour Protection

The area of the berm comprising the plow-hole should be repaired. This hole could be filled with granular material, especially since the weak soil has been somewhat stabilized by the pipeline refrigeration system and would probably support the material. Any areas where the berm's granular cover has been eroded or scraped away should be repaired as this cover is the key to protecting the berm from thermal erosion. This was emphatically illustrated by the ice drilling platform which lost 2 m of ice off the top over the summer months.

In view of the high cost of running the refrigeration system (approximately $10,000.00/day) and in view of the limited effectiveness of the frozen bulb produced in resisting ice scour, it is recommended that system not be used at all and that scour protection be left to the berm. The refrigeration system could be useful during production of the well to prevent thawing of already frozen soils by warm gas and would be cheaper to operate at that time.

It is recommended that, in the future, where weak soils of considerable depth near shore are encountered, that scour of pipelines should be prevented by burying the pipe deep near shore so it is below the zone of possible scour. Newly developed tunneling and directional drilling methods make this feasible. If extra protection is needed, the feasibility of permanent ice structures anchored to shore has been demonstrated.

Sandwell

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: May 9, 1980

Drake Point Offshore Pipeline Ice Berm for Near Shore Scour Protection Monitoring Summer 1979

INTRODUCTION

In April of 1978, a marine flowline was completed which brought gas ashore from Panarctic's Drake F-76 well off the Sabine Peninsula of Melville Island in the High Arctic. (See location plan shown in Figure 1). A grounded ice berm was constructed to protect the flowline to the 5 m water depth contour from potential near shore scouring by ice masses in the area (Reference 1,2).

During the first summer season of operation, a refrigeration system was used to create a bulb of frozen soil around the pipeline to provide added protection from ice scour to a distance of 280 m offshore. Due to the associated high costs, the refrigeration system was not operated after the first season. Since then, the ice berm and the remnants of the frost bulb have been the means of protection for the flowline from ice scouring.

This report contains the results of second-year monitoring of the ice berm and the frost bulb around the pipeline.

SUMMARY

Analyses of the photographs show that deterioration of and loss of material from the berm during the second year in operation was limited to less than 5% of the total area. This loss was confined to the northern perimeter, mainly near the flowline. No significant deterioration occurred along the east and west perimeters. Two large pieces which had broken off the east and north edges the previous year have completely deteriorated. Two large stress cracks in the N.W. and N.E. sections of the berm, observed the previous year, have remained static.

The 1 m insulating gravel cover continues to maintain ice temperatures in the bulk of the berm below freezing. This gravel has eroded where 'spring' runoffs have created rivulets. Some sink holes were also in evidence, especially near the flowline and plowhole.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: May 9, 1980

Drake Point Offshore Pipeline Ice Berm for Near Shore Scour Protection Monitoring Summer 1979

Photo monitoring of the berm and offshore vicinity showed more ice cover than last year. No large ice floes came in contact with the berm nor were any large multi-year floes observed to enter the bay during the summer. As in the previous year, undercutting of the berm edge at the water line was in evidence, this undercutting being about 2 m, the same as the previous season. Thus the undercut remained nearly static since the first summer. Material from above this undercut may slough off, allowing more sloughing to take place.

Temperatures taken along the pipeline show that deterioration of the frost bulb around the pipeline continues since operation of the refrigeration system ceased. In general, less that 0.5 m of soil around the pipeline is -4°C or colder.

The thermistor strings through the berm show that it is cooling and the -2°C isotherm, taken as the limit of frozen soil, is descending through the berm and into the soil beneath. At the S.W. thermistor string 4.5 m of freezing occurred between November 10, 1978, and April 29, 1980. Water layers found at the time of installation of the thermistors have now been frozen. The berm is behaving as anticipated and is becoming part of the shoreline.

RECOMMENDATIONS

Based on the observations made and measurements taken at the flowline shore approach during the past year the following recommendations are made:

1. Efforts should be made to patch the major sink holes and to fill in the rivulets formed during runoff. Spare granular material for this purpose is stockpiled in the S.W. corner of the berm.

2. Efforts should be made to divert any major runoff of water from eroding the berm and creating sink holes and rivulets. Remedial work on the granular cover of the berm near original shoreline would probably take care of this.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: May 9, 1980

Drake Point Offshore Pipeline Ice Berm for Near Shore Scour Protection Monitoring Summer 1979

3. Little can be done at present to stop undercutting at the north end of the berm near the waterline. This undercut area should be watched carefully and measurements and photographs should be taken during any site visits.

4. Visits to the site should be made two or three times during the summer. Temperature readings on the thermistor strings and photos should be taken during these visits. Good aerial photographs are particularly useful.

5. The Nikon F2AS camera should be installed again this year to monitor any ice impingement on the berm. This unit has been made operable by battery without aid from the thermal generators and the blower has been eliminated. Power requirements are small and installation has been simplified.

6. Near the end of the summer a survey of the berm should be conducted. Linear measurements of the perimeter should be obtained and levels should be taken on the reference pins installed on the berm.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 7, 1980

Offshore Drilling Ice Platform Whitefish H-63A

INTRODUCTION

The site for Whitefish H-63A was the same as the previous season's Whitefish H-63 site. Whitefish H-63's relief pad 1 was used as H-63A's main pad 1 and H-63's main pad 4 was used as H-63A's relief pad 4.

The thick multi-year ice in the area was sufficient to support Rig 1 with only minor flooding being required to level the platform.

SITE	START FLOODING	COMPLETE FLOODING	INITIAL THICKNESS	FINAL THICKNESS	START RIG-UP	SPUD DATE	RELEASE DATE
Whitefish H-63A	Oct. 31/79	Nov. 8	6.93 m	7.24 m	Nov. 10	Dec. 3	May 15/80

CONCLUSIONS AND RECOMMENDATIONS

The Rig 1 187 day loading duration at Whitefish H-63A represents the longest rig load duration achieved on an ice platform. The typical load duration for an ice platform deep hole (3000+ m) is in the order of 90 - 100 days but due to the long testing program at Whitefish considerably more time was required. In future cases the only time that 190 day duration load cases should occur would be in extremely thick multi-year ice cases where the ice platform construction period would be in the order of 3 - 4 weeks. In such long duration load cases the predicted deflection would have to be altered slightly to reflect the extra load duration. The difference however, is not considerable.

The Rig 1 loading at Whitefish H-63A was identical to the Hazen F-54 loading with a long term load of 1304 tonne.

The average ultimate borehole compressive strength for the 24 tests done at Whitefish H-63A on Nov. 9, 1979 was 18.12 MPa. This value is slightly lower than the value recorded at Whitefish H-63 (21.6 MPa) under similar ice conditions.

The tide recorder at Whitefish H-63A worked very well as it appears very little anchor settlement occurred and the datum was not lost during the tide record. Previous experience, however, has shown the anchor settlement can be quite a problem for offshore tide gauges and for this reason we recommend either using an umbrella or penetration type of anchor. The umbrella anchor basically is an anchor which spreads below the ice surface to present a high surface area to weight ratio while the penetration anchor uses a pounding mechanism to penetrate the anchor into harder bottom mud.

The melting of a 7.0 m x 6.7 m x 7.0 m cavity in the ice platform near the disposal line at Whitefish H-63A was an undesirable occurence. Care should be taken in the future to ensure that the two sections of the 12 m discharge pipe do not separate and leave a 6 m pipe which disposes waste at the ice-water interface as occurred at Whitefish H-63A.

Overall with the exception of the large melted cavity the construction and operation of the ice platform at Whitefish H-63A was uneventful. Although this fact limits the discussion of the platform, it does ensure a safe operation for all the people involved.

Sandwell

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: November 11, 1980

Offshore Drilling Ice Platforms Char G-07 and Balaena D-58

Overview:

The construction and performance of the ice platforms at Char G-07 and Balaena D-58 have given further important performance data relevant to the ice platform projects.

The operation of Rig 2 at Balaena D-58, although on a small scale when compared to the other heavier rigs in the Arctic, should not be overlooked. The performance data from this rig on various ice platform thicknesses has allowed us to determine the relationship between ice thickness and long-term deflection. This data has been most important in the design of the ice platforms for the heavier rigs.

The building of the Rig 4 ice platform at Char G-07 introduced a new method of ice platform construction to the Arctic. In order to test the feasibility of decreasing the required ice thickness by increasing the buoyancy of the platform through the use of foam, 271 m^3 of urethane foam was frozen into the neutral axis area of the Char G-07 ice platform.

The 271 m^3 of urethane foam results in a reduction of ice platform weight of 241.2 tonne. Thus the long-term rig load for Rig 4 of 678.6 tonne could be reduced to a resultant long term load of 437.4 tonne for the ice platform design.

This 241.2 tonne long-term load reduction was noted to decrease the required ice platform thickness, based on long-term deflections, by 0.9 m for both the first-year and multi-year ice platforms. At a typical daily buildup rate of 76 mm/day this represents a saving of 12 days. It should be emphasized, however, that this saved time was not a factor in the use of urethane foam at Char G-07. The reasons for its use were to test the theories and construction methods relevant to ice platform design.

Laboratory test on the urethane foam showed an average compressive strength of 110.7 kPa which was above the 100 kPa specified in the design. Also water penetration tests showed an average water absorption of 1.8% for 8 samples removed from the in-place blocks on March 15, 1980. This was well below the 5% assumed in the design.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: November 11, 1980

Offshore Drilling Ice Platforms Char G-07 and Balaena D-58

The long-term deflection performance of the Char G-07 platform is the most important performance parameter. At the start of deflection measurements, the average freeboard taken at the 10 design-thickness stations was 13.7%. A solid ice platform has a usual freeboard of 11%. Thus there was 2.7% or .14 m of excess freeboard due to the buoyancy of urethane foam cells. The first .14 m of settlement due to rig load brought the ice platform to the 11% freeboard line which is the level from which we normally measure our deflections. Since a total deflection of 0.390 m was observed from start of rig-up, the settlement below the 11% freeboard level was .25 m. This amount of settlement was exactly as predicted and this fact has added confidence in the methods used to predict the results.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: June 30, 1981

Drake Point Offshore Pipeline Ice Berm for Near Shore Scour Protection Monitoring Summer 1980

INTRODUCTION

In April 1978, a marine flowline was completed which brought gas ashore from Panarctic's Drake F-76 well off the Sabine Peninsula of Melville Island in the High Arctic. (See location plan shown in Figure 1). A grounded ice berm was constructed to protect the flowline to the 5 m water depth contour from potential near shore scouring by ice masses in the area (Reference 1 and 2).

During the first summer season of operation, a refrigeration system was used to create a bulb of frozen soil around the pipeline to provide added protection from ice scour to a distance of 280 m offshore. Due to the associated high costs, the refrigeration system was not operated after the first season. Since October 3, 1978, the ice berm and the remnants of the frost bulb have been the means of protection for the flowline from ice scouring.

This report contains the results of third-year monitoring of the ice berm and the frost bulb around the pipeline.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: June 30, 1981

Drake Point Offshore Pipeline Ice Berm for Near Shore Scour Protection Monitoring Summer 1980

SUMMARY

Analysis of the aerial and closeup photos show that pieces which broke off in 1979 had completely deteriorated by the end of the 1980 summer season. No large pieces broke away during the 1980 season. Two large stress cracks in the N.W. and N.E. sections of the berm observed for two years, have remained static. Deterioration of the berm edge was constant in all areas and limited to one to two metres. This would be due to wave and tidal action and the resultant undercutting. Undercutting on the north side of the berm was less than in 1979. Deterioration of the berm has slowed since 1978. The rivulet west of the flowline area deepened and was probably the cause for the beach which appeared in that area. Repair work was carried out on the front of the berm which involved filling in the rivulet and sinkholes caused by spring runoffs.

Photo monitoring of the berm and offshore vicinity showed less ice cover than last year with frequent movement of ice floes across the front of the berm. Ice which came in contact with berm was no more than 1 m in thickness. In three years of monitoring this was the first year that the large ice pack further offshore drifted out of the bay.

Temperatures taken along the pipeline show that deterioration of the frost bulb around the pipeline continues at a slow rate since operation of the refrigeration system ceased.

The thermistor strings through the berm show that it is cooling and -2°C isotherm, taken as the limit of frozen soil, is descending deeper into the soil beneath.

At the S.W. thermistor string 1.5 m of freezing occurred between August 19, 1979 and August 27, 1980.

Settlement of the west side of the berm was approximately 25 cm in the period May 1978 to August 1980. On the east side it is negligible.

The berm continues to behave as anticipated and is becoming part of the shoreline and, thus, its deterioration rate is slowing.

RECOMMENDATIONS

Based on the observations made and measurements taken at the flowline shore approach during the past year, the following recommendations are made:

1. Following last summer's example of remedial work on the berm cover (1980), efforts should be made to patch the major sinkholes and to fill in the rivulets formed during runoff.

2. Efforts should be made to divert any major runoff of water from eroding the berm and creating sinkholes and rivulets. Remedial work on the granular cover of the berm near original shoreline would probably take care of this.

3. Little can be done at present to stop undercutting at the north end of the berm near the waterline. This undercut area should be watched carefully and measurements and photographs should be taken during any site visits.

4. Visits to the site should be made two or three times during the summer. Temperature readings on the thermistor strings and photos should be taken during these visits. More attention should be spent on attaining a good set of aerial photographs.

5. The Nikon F2AS camera should be installed again this year to monitor any ice impingement on the berm. This unit has been made operable by battery without aid from the thermal generators and the blower has been eliminated. Power requirements are small and installation has been simplified.

6. Near the end of the summer a survey of the berm should be conducted. Linear measurements of the perimeter should be obtained and levels should be taken on the reference pins installed on the berm.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 1, 1981

Offshore Drilling Ice Platform Cisco B-66

Overview:

The Cisco B-66 wellsite was an area of extremely thick hummocked multi-year ice (up to 12 m) with pressure ridge in the region. The presence of the extremely thick and rough multi-year ice enhanced the performance of the platform while at the same time creating unforeseen difficulties in the construction of the platform and especially the airstrip.

The Rig B loading period was approximately 100 days. This is a normal load duration for ice platforms. The loading at Cisco B-66 was 1304 tonnes, similar to two previous Rig B platforms – Hazen F-54 and Whitefish H-63A.

The average confined compressive strength for 13 tests done on January 24, 1981 was 21.7 MPa.

Ice temperatures during the drilling season showed a very safe stable range through the ice platform. Circulation of water in the moonpool served to keep the area frozen. The moonpool refrigeration system using Synflex hose was not as effective as was hoped. A temperature change of only -0.5°C was noted after start-up of the system.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 5, 1981

Offshore Drilling Ice Platform Skate B-80

Overview:

The relatively thick multi-year ice that was present, coupled with the fact that no pressure ridges were encountered, made for an early start of rig-up date. The significant dates of operation at Skate B-80 are

SITE	START FLOODING	COMPLETE FLOODING	INITIAL THICKNESS	FINAL THICKNESS	START OF RIG-UP	SPUD DATE	RELEASE DATE
Skate B-80	Dec. 1, 1980	Dec. 23, 1980	3.90 m	5.43 m	Dec. 28, 1980	Jan. 20, 1981	Apr. 4 1981

The design criteria which dictate the dimensions of an ice platform are that:

a) long-term settlement be limited to available freeboard;

b) any combination of stresses within the ice platform, due to short-term and long-term loads be limited to 500 kPa.

In order to ensure that the above two conditions are met, the average thickness of the ice platform over the design area must be greater than a stipulated design thickness. Over recent years Panarctic have viewed the design thickness as a minimum ice thickness while requiring, where possible, that the ice platform be built to an optimum thickness which is 10% greater than the design thickness.

The Skate B-80 wellsite was an area of relatively thick multi-year ice which resulted in an early start of rig-up date of December 28, 1980.

The average confined compressive strength for 10 tests done on January 17, 1981, was 23.6 MPa. This value is slightly higher than the value recorded at Whitefish H-63 (21.6 MPa).

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 5, 1981

Offshore Drilling Ice Platform Skate B-80

Ice temperatures in the platform remained within expected limits throughout the drilling season even without the refrigeration system in operation. However, in an extended drilling season this system would have played an important role in keeping ice temperatures cold.

Tides recorded were of good quality. The new penetration-type anchor has reduced sea bottom settlement. Problems were encountered with the use of this anchor but tide datum was not lost due to the presence of a second anchor system. In future, a two-anchor system is recommended in conjunction with the umbrella-bearing anchor that was used at MacLean I-72.

The measured maximum deflection was 317 mm which left an available freeboard of 350 mm after 90 days of rig loading.

The melting of a 9 m X 9 m X 5.5 m cavity at the rig disposal line was an unfortunate incident. Care should be taken in future to monitor the temperature of fluids being disposed down this line.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 15, 1981

Offshore Drilling Ice Platform MacLean I-72

INTRODUCTION

The construction and drilling program at MacLean I-72 proved to be a credit to the personnel in all phases of the project. In particular, the construction of the ice platform proceeded at a rate which saw the final flooding date earlier than has occurred before for such a heavy-rig platform.

Start Flooding	Complete Flooding	Initial Thickness (m)	Final Thickness (m)	Start of Rig-Up	Spud Date	Release Date
Nov. 30 1980	Jan. 1 1981	2.79	6.24	Jan. 2 1981	Jan. 27 1981	Apr. 27 1981

Overview:

The construction of the Rig A ice platform at MacLean I-72 proceeded more rapidly than ever before with the final flooding date of January 1, 1981. The relatively high 105 mm/day built-up rate and the use of 553.3 m^3 of urethane foam were the reasons for completing the flooding in such a short period.

Between November 27 to December 1, 1980, Engineered Urethanes Ltd. of Edmonton manufactured 48 urethane foam blocks for use in the ice platform. The use of this foam material reduced the weight of the ice platform by 500 tonnes without reducing its structural stiffness. This in effect allowed this platform to carry an additional rig load of 500 tonnes over the drilling period.

During the construction of the 48 foam blocks 13 foam samples were tested to determine the actual density of the blocks. The results indicated an average density of 37.0 kg/m^3; higher than the design density of 26.0 kg/m^3.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 15, 1981

Offshore Drilling Ice Platform MacLean I-72

A carefully planned flooding schedule at MacLean helped to achieve the high rate of ice buildup. When winds were below 4.9 m/sec. (10 knots), nozzles were frequently used to achieve a high rate of heat transfer. When winds were between 4.9 - 9.8 m/sec. (10 - 20 knots) flooding was carried out in the usual manner. When winds were between 9.8 - 14.7 m/sec. (20 - 30 knots) upwind flooding was used to take the snow out of the air. And finally when winds were greater than 14.7 m/sec. (30 knots) all flooding was stopped.

Temperature monitoring of the ice during flooding, with the use of thermistor banks, showed the highest average ice temperature recorded was -6.6°C. This was well below the maximum allowable high of -5.0°C.

On January 4, 1981, two days after the completion of flooding at MacLean I-72, an average confined borehole ice strength of 13.7 MPa was recorded of built-up ice. This value was higher than the 11.3 MPa strength recorded at Hazen F-54 for tests in built-up ice upon completion of flooding.

On January 1, 1981, the average ice thickness over the design area was measured at 6.24 m and the average freeboard was 0.850 m or 13.6% of the average ice thickness.

Since the ice was sufficiently thick to accommodate all types of aircraft, only levelling of the airstrip was necessary. Because of the limitations of the machinery, however, the construction period was quite long. The 727 jet strip was completed on January 13, 1981.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 15, 1981

Offshore Drilling Ice Platform MacLean I-72

The use of synflex hose, in the refrigeration system around the outside of the moonpool cribbing, was not successful. It is recommended that copper coils be reconsidered in future refrigeration system. In addition, the Tioga which heats the subsea area should be regulated for heat. The relatively high (-4°C) temperatures which were observed in the platform below the subsea area were warmer than in previous years.

Vertical ice platform deflections were measured daily with an automatic level and a continuous-plot freeboard recorder which gave maximum deflection of 458 mm and 435 mm respectively below the 13.6% freeboard level. The survey deflection of 458 mm was judged as the more accurate and a deflection of 298 mm below the 11% freeboard level was calculated.

This agrees rather well with the predicted long-term deflection of 390 mm below the 11% freeboard level for Rig A on a 6.24 m ice platform.

A study of the strain data from MacLean I-72 and other platform sites revealed that a strict relationship exists between platform strain rate, ice thickness and platform deflection rate.

In an effort to determine the hydrostatic position of the MacLean I-72 ice platform with the 553.3 m^3 of urethane foam, a float recorder was installed on the platform while the rig was removed. Data from this recorder illustrated that after an ice platform supports a rig load for a winter season it becomes severely deformed and does not readily rebound to its preload level.

Sandwell

GEOTECHnical RESOURCES LTD. **CLIENT: PANARCTIC OILS LTD. ET AL** **REPORT DATE: September 1982**
Ice Platform Construction Manual Cape Allison C-47, Rig A

Overview:

This internal manual outlines procedures for the construction of the ice platforms at the Cape Allison C-47 location. The well will be drilled to about 2100 metres by Rig A.

King Christian Island will be used as a staging base for the ice camp and equipment. Logistics are outlined in Items 1-17.

The ice platforms should be construction to the following ice thicknesses:

Description	First Year Ice	Multi-Year Ice
Minimum Thickness Rig A	6.2m (20.3 ft)	6.0 m (19.7 ft)
Optimum Thickness Rig A	6.8 m (22.3 ft)	6.6 m (21.6 ft)
Minimum Thickness Rig 4	5.1 m (16.7 ft)	4.9 m (16.1 ft)
Optimum Thickness Rig 4	5.6 m (18.4 ft)	5.4 m (17.7 ft)

Flooding procedures, Main Pad Pump Installation, Relief Pad Pump Installation and Reporting procedures are identified in the manual.

GEOTECHnical RESOURCES LTD.
CLIENT: PANARCTIC OILS LTD. ET AL
REPORT DATE: September 1982

Ice Platform Construction Manual N. Buckingham B-69, Rig A

Overview:

This internal manual outlines procedures for the construction of the ice platforms at the Buckingham B-69 location. The well will be drilled to about 2500 metres by Rig A.

Graham Island will be used as a staging base for the ice camp and equipment. Logistics are outlined in Items 1-17.

The ice platforms should be construction to the following ice thicknesses:

Description	First Year Ice	Multi-Year Ice
Rig A with foam*	5.6 m (18.4 ft)	5.6 m (18.4 ft)
Minimum Thickness Rig A	6.6 m (21.6 ft)	6.4 m (21.0 ft)
Optimum Thickness Rig A	7.3 m (24.0 ft)	7.1 m (23.3 ft)
Minimum Thickness Rig 4	5.1 m (16.7 ft)	4.9 m (16.1 ft)
Optimum Thickness Rig 4	5.6 m (18.4 ft)	5.4 m (17.7 ft)

***To be used only if original ice thickness is less than 3 m.**

Flooding procedures, Experimental Flooding Procedures, Pump Installation, and Reporting procedures are identified in the manual.

Sandwell

GEOTECHnical RESOURCES LTD.
CLIENT: PANARCTIC OILS LTD. ET AL
REPORT DATE: September 1982

Ice Platform Construction Manual N. Buckingham L-71, Rig A

Overview:

This internal manual outlines procedures for the construction of the ice platforms at the North Buckingham J-71 location. The well will be drilled to about 2800 metres by Rig A.

Graham Island will be used as a staging base for the ice camp and equipment. Logistics are outlined in Items 1-17.

The ice platforms should be construction to the following ice thicknesses:

Free Flooding	First Year Ice	Multi-Year Ice
Minimum Thickness Rigs A & C	6.2 m (20.3 ft)	6.0 m (19.7 ft)
Optimum Thickness Rigs A & C	6.8 m (22.3 ft)	6.6 m (21.6 ft)
High Pressure Spray		
Minimum Thickness Rigs A & C	6.5 m (21.3 ft)	Use free-flooding
Optimum Thickness Rigs A & C	6.9 m (22.6 ft)	Method

Flooding procedures, Main Pad Pump Installation, Relief Pad Pump Installation and Reporting procedures are identified in the manual.

GEOTECHnical RESOURCES LTD.
CLIENT: PANARCTIC OILS LTD. ET AL
REPORT DATE: September 1982

Ice Platform Construction Manual N. E Drake L-06, Rig B

Overview:

This internal manual outlines procedures for the construction of the ice platforms at the N.E. Drake L-06 location. The well will be drilled to about 1300 metres by Rig A.

Drake F-76 will be used as a staging base for the ice camp and equipment. Logistics are outlined in Items 1-17.

The ice platforms should be construction to the following ice thicknesses:

Description	First Year Ice	Multi-Year Ice
Minimum thickness Rig B	6.2 m (20.3 ft)	5.9 m (19.4 ft)
Optimum Thickness Rig B	6.8 m (22.3 ft)	6.5 m (21.3 ft)
Minimum Thickness Rig 4	5.1 m (16.7 ft)	4.9 m (16.1 ft)
Optimum Thickness Rig 4	5.6 m (18.4 ft)	5.4 m (17.7 ft)

Flooding procedures, Main Pad Pump Installation, Relief Pad Pump Installation and Reporting procedures are identified in the manual.

FENCO CONSULTANTS LTD. / LAVALIN
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: September 15, 1982

Offshore Drilling Ice Platform Cisco C-42

Overview:

The initial average rig 4 design ice thickness of 5.69 m required only a minimal amount of flooding. Most of this work was concentrated in the tapered zone of the platform.

A mobile flooding unit and a backhoe were employed to excavate the main and relief platform moonpools. This procedure substantially reduced the number of man-hours that would ordinarily be required to complete the moonpools and released personnel for other duties.

The late rig-up date of February 10 allowed the moderately thick, multi-year ice at the wellsite time to reach a colder, stronger state. On January 29, two weeks after flooding was completed, borehole jack tests were conducted. The ultimate confined compressive strengths averaged 29.4 MPa. These high strength values are indicative of very strong, good quality ice found in multi-year ice floes which are left unoccupied and allowed to cool to a low temperature.

The actual long-term deflection of -228 mm was 26% greater than the predicted deflection from previous load cases. The large difference is due to the close proximity of a first-year lead to the wellsite. The weight of the rig on the edge of the multi-year floe resulted in a higher actual deflection.

The two anchor tidal recording system operated acceptably and continuously throughout the drilling period. The freefall anchor stabilized on the ocean floor on January 16. Thereafter, the two anchor systems displayed identical tidal fluctuations.

Ice platform thermistor readings, throughout the entire drilling period, indicate a very stable, safe ice temperature condition. At the date of rig release ice temperatures averaged -8.1°C at the centre of the platform.

The extension of the vertical section of the rig disposal pipe to 18 m below the ice surface effectively eliminated the previous problem of ice decay. A thermistor bank was installed near the rig disposal line to monitor ice conditions. No evidence of ice decay was found.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: September 16, 1982

Offshore Drilling Ice Platform Cape Mamen F-24

Overview:

The Cape Mamen F-24 well marked the first time that Panarctic Rig C has operated from an offshore ice drilling platform. The design of the Panarctic Rig C platform was identical to the platform for Panarctic Rig A due to duplication of rig weights and layout. Over the design area the required average ice thickness for Rig C is 6.6 m and 6.4 m on a first-year and multi-year ice platform respectively.

The initial profiled average thickness of 4.59 m meant that the Rig C platform could be classed as a multi-year ice platform and a final average thickness of at least 6.4 m would be required. The profiled final average ice thickness over the design area of the Rig C pad at Cape Mamen F-24 was sufficient at 6.60 m.

The November 30, 1981, start of flooding date on the main pad at this site is typical for an ice platform in this area. In previous years the Maclean I-72, Char G-07, and Hazen F-54 had start-of-flooding dates of November 30, November 14 and November 19 respectively.

The total dead weight and variable long-term loads for Rig C while operating from an ice platform are 1000.9 tonnes and 628.8 tonnes for a total 90 day load of 1630 tonnes. This design rig load is for a water depth of 420 m, however, the 363 m water depth at Cape Mamen F-24 caused only a slight reduction in the above load therefore the 1630 tonnes will be used to represent the long-term load.

The construction period in various aspects was affected by the unusually warm weather conditions up to December 15, 1981 (rarely did air temperature fall below -30°C). The average buildup rate of 80 mm/day over the flooding period could have been increased given consistently colder weather.

Temperature monitoring during the drilling period revealed that the ice platform was experiencing unusually warm temperatures and measures were taken to reduce the heat input from the rig. Therefore, we can conclude that the temperature monitoring program served as a useful tool in ensuring that the ice platform was operated in a safe manner.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: September 16, 1982

Offshore Drilling Ice Platform Cape Mamen F-24

Strain monitoring in the ice platform around the perimeter of the moonpool proved to be of limited success. Due to warm ice temperatures below the subsea shop, the gauges in this area were not properly anchored and strain results are therefore not valid. Strain rosettes 9 m from the moonpool and in the area of the pipe rack and mud tanks, however, were functional and accurate data was collected at these locations.

A maximum long-term deflection of .447 m was measured at Y1 by level survey at Cape Mamen F-24. This value is 10% lower than the value of .500 m predicted by the use of the ice thickness, long-term load versus long-term deflection equation.

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FENCO CONSULTANTS LTD. / LAVALIN
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: September 16, 1982

Offshore Drilling Ice Platform Sculpin K-08

Overview:

The Sculpin K-08 well was the second offshore well drilled with Rig A; the first was completed over the 1980-81 winter season at the MacLean I-72 site.

Sculpin K-08 was the thickest multi-year ice platform encountered to date for an offshore well. The platform construction period was essentially an extensive ripping and grading operation with minimal flooding required for levelling purposes.

START FLOODING	COMPLETE FLOODING	INITIAL THICKNESS	FINAL THICKNESS	START OF RIG-UP	SPUD DATE	RELEASE DATE
Dec. 3 1981	Jan. 2 1982	10.10 m	10.35 m	Jan. 3 1982	Jan. 27 1982	May 3 1982

Introduction:

The extremely thick ice encountered at Sculpin K-08 enhanced the performance of the platform. The final average thickness within the design area was 47% greater than the optimum requirement of 7.1 m on multi-year ice. While the deflection power relationship does not accurately predict the actual deflection at Sculpin K-08, the available freeboard recorded at the time of maximum deflection was 1.003 m indicating a very safe platform.

Borehole jack tests at Sculpin K-08 yielded excellent ice strength results. The average confined compressive strength for 41 tests on April 7, 1982 was 25.7 MPa and the average value of the elastic modulus was 2908 MPa.

The average ice temperatures recorded through the main platform remained well below the accepted safe value of -5°C. On April 26, 1982 an average temperature of -7.5°C was recorded on thermistor bank ACG which is indicative of the platform as a whole (directly under the rig). Ice temperatures close to the moonpool were somewhat higher averaging approximately -2°C. This was due in part to the inoperative condition of the moonpool refrigeration system as well as to the fact the ice in this vicinity is in close proximity to the seawater. An underwater T.V. inspection showed no deterioration of the ice around and below the bottom of the moonpool crib.

The construction period was essentially a ripping operation by D3 and D4 dozers with minimal flooding required for levelling. Ice which was ripped from the high areas of the platform was placed in 0.3 - 0.5 thick lifts over the low areas. This method which accelerates the freezing process, allowed for longer individual floods and effectively shortened the flooding program.

The problem of continual power outages with the simultaneous running of two or more of the four electric submersible pumps significantly increased the total flooding time, however, there was no delay in the start of rigup. This problem nevertheless should be rectified for future platform construction where substantial delays could occur in a long flooding program. The use of a backhoe at Sculpin to excavate for the moonpool crib was a tremendous improvement over the previous method of using chainsaws and manual labour. Whereas in the past this operation took up to five days to complete, it was done at Sculpin in one day. A backhoe should be standard equipment for future platform construction particularly on thick multiyear ice.

The excavation for the moonpool crib should be limited to a depth of no more than 5 m in thick multi-year ice. This would reduce the possibility of water seeping into the excavation which usually occurs at a depth below 5 m.

The practice of building the crib inside the moonpool excavation should be adopted whenever possible since it eliminates the possibility of damaging the crib while also guaranteeing a square and level structure.

The tide data recorded at Sculpin K-08 was of excellent quality. The use of the umbrella type anchor appears to have solved the problem of anchor settlement and erroneous tide data associated with other type anchors in previous years.

There were no spills reported within the fuel storage area but the advantages of the Level Area Bladder Farm were still evident. A grader was used regularly to keep the area clear of snow thus increasing the validity of the daily inspection. The problem of the fuel containers being spaced too close together was remedied quickly without incident but care should be taken in the future to space the containers a minimum of 6 m apart.

FENCO CONSULTANTS LTD. / LAVALIN
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: September 17, 1982

Offshore Drilling Ice Platform Whitefish A-26

Overview:

The main platform was located on thick, multi-year ice. Flooding commenced on November 24 and was completed on December 19 for a final average ice thickness of 7.07 m and an average buildup of 0.46 m, representing an average daily buildup of 18 mm per day.

Flooding of the airstrip began on November 16, 1981 and was completed to 1830 m on December 30, 1981. Twenty-six borehole jack tests were completed on December 16, 1981, for an average ultimate confined compressive ice strength of 13.9 MPa.

Borehole jack tests were completed on December 19, 1981, the day of the final flood on the main pad. Thirty tests were completed at three different sites for an average confined compressive strength of 26.2 MPa. This value is slightly higher than the previous results found at Cisco B-66 and Whitefish H-63A and indicated the very high strength qualities of the multi-year ice at Whitefish A-26.

SITE	START FLOODING	COMPLETE FLOODING	INITIAL THICKNESS	FINAL THICKNESS	START OF RIG-UP	SPUD DATE	RELEASE DATE
White-fish A-26	Nov. 24 1981	Dec. 19 1981	6.61 m	7.07 m	Dec. 25 1981	Jan. 15 1982	Apr. 30 1982

The predicted 90 day long-term deflection, based on the 1340 metric tonne design load, was 0.365 m while the actual maximum level survey deflection was 0.326 m. The difference between the predicted and actual deflection was 10.7%. This result provides further confidence in the use of the equation for predicted long-term deflections.

The two anchor tide recording system operated effectively throughout the entire construction and drilling programs. The highest tide was recorded on March 9, 1982 (1609 mm) and the lowest tide was recorded on December 13, 1981 (449 mm) for a total range of 1160 mm.

FENCO CONSULTANTS LTD. / LAVALIN
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: September 17, 1982

Offshore Drilling Ice Platform Whitefish A-26

Ice platform thermistor measurements of the Whitefish A-26 main platform indicate very stable safe ice temperatures during the entire drilling program. Thermistor beads near the bottom of the ice platform at the end of the drilling program reached a temperature of -1.5°C. With the operation of the lower refrigeration coils, ice temperatures would have remained at a colder state.

The installation into the ice of a double length of vertical disposal pipe and the careful monitoring of rig discharge temperatures resulted in a minimal amount of ice erosion at the rig disposal line.

Throughout the field operating season, FENCO on-site personnel monitored the level area fuel storage system daily. No major spills occurred at Whitefish A-26. The ease with which the undyked bladder farm system was monitored and cleared of snow indicates the effectiveness of this design.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 19, 1983

Offshore Drilling Ice Platform Cisco K-58

Overview:

This report covers the construction and performance of the offshore ice platform Cisco K-58.

The operation of Panarctic Rig B at Cisco K-58 marked the sixth time this rig has operated from an offshore platform. Close monitoring of the ice quality relative to temperatures and strength at Cisco K-58 proved to be quite useful as a zone of low strength ice below the generator area of the rig required attention in order to ensure that a problem did not develop.

The October 24 commencement of flooding operations at Cisco K-58 marked the earliest start to date for an offshore ice platform. The presence of thick multi-year ice contributed to a relatively short construction period lasting approximately 3-1/2 weeks. Flooding for the airstrip was carried out in an area of first-year ice. No difficulties were encountered in this phase of the operation.

START FLOODING	COMPLETE FLOODING	INITIAL THICKNESS	FINAL THICKNESS	START OF RIG-UP	SPUD DATE	RELEASE DATE
Oct. 24 1982	Nov. 18 1982	4.98 m	6.64 m	Nov. 20 1982	Dec. 6 1982	Mar. 28 1983

After flooding was complete, borehole jack testing on November 18 and 20 revealed an average built-up ice confined compressive strength of 10.8 MPa for seven tests. In the multi-year ice near the moonpool an average confined compressive strength of 23.6 MPa for 21 tests was noted. However, at Station GC an average confined compressive strength of 9.8 MPa for six tests was recorded in the multi-year ice. The low ice strengths at Station GC illustrated the fact that this area was a zone of low relief where water must have ponded before freeze-up. Snow cover after the start of freeze-up evidently kept this area of water-saturated ice from freezing properly and subsequent flooding over the area ensured the existence of warm ice temperatures.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: October 19, 1983

Offshore Drilling Ice Platform Cisco K-58

A detailed study of platform ice strengths at the end of the winter season was carried out to determine the extent of the ice erosion under the rig matting. In total, 199 individual borehole tests were completed over the platform rig area for an average strength of 14.7 MPa for all tests. Again the average borehole strength at Station GC of 10.8 MPa proved to be the zone of lowest strength on the pad area. During this testing process distinction between multi-year and built-up ice was not made. Visual records of the top surface of the ice platform showed that a considerable amount of heat from the rig complex was migrating down into the ice surface and it was concluded that two layers of purlboard should be placed under the rig matting for future ice platforms.

Also presented within this report is a study on the relationship between lab tested ice unconfined compressive strength and field tested borehole compressive strengths. Briefly, it was found that for the granular built-up ice, the ratio of confined to unconfined strength was 2.9 which compared well to the expected value of 3.0. However, for the natural columnar grained ice the ratio of confined to unconfined strength was not as expected due to the fact that the borehole testing and uniaxial testing were done in perpendicular ice crystal direction.

In summary, the construction and monitoring of the ice platform at Cisco K-58 has given important new experience to the people involved with the ice platform programs. The early start of rig-up on November 20, 1982, and the slightly low ice strengths have illustrated the extent to which ice platforms can be used over a winter season.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: February 3, 1984 (Final)

Offshore Ice Platform Grenadier A-26

Overview:

The Grenadier A-26 platform was of special interest since this was the first time Panarctic Rig C had operated from first-year ice conditions. The initial and final ice thicknesses were 1.3 m and 6.87 m on November 14, 1982, and January 13, 1983, respectively. The overall average buildup rate was calculated at 87.5 mm/day giving consideration for a shift in the pad axis after the start of flooding.

The Hercules airstrip was flooded from November 10, 1982, to January 5, 1983. On December 11, 1982, a lead opened up through the strip requiring the strip to be extended. This in turn lengthened the flooding period. The ice quality proved to be excellent, as the borehole jack tests conducted on January 1, 1983, showed an average ultimate borehole compressive strength of 16.7 MPa, 39% above the minimum allowable airstrip strength of 12.0 MPa.

The ice quality on the main platform was quite good. The four holes tested in January, after completion of flooding, showed an average ultimate borehole compressive strength of 14.0 MPa for 35 individual tests. A similar series of tests later in the season, during April, showed that the average strength had increased to 19.5 MPa.

Ice temperatures at Grenadier remained low and steady throughout the drilling period. The moonpool cooling system of 50 mm diameter steel pipe joined by synflex hose proved successful in operation. Also, at the insulated rig disposal line, there was virtually no rise in temperature or ice decay.

The strain gauge program generated accurate strain results from one rosette. The data from this rosette showed a virtual zero magnitude strain in approximately the radial direction from the moonpool and a 1000 microstrain maximum in the tangential direction.

FENCO CONSULTANTS LTD.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: February 3, 1984 (Final)

Offshore Ice Platform Grenadier A-26

At this site an innovative attempt was made to measure the stresses generated within the upper compression zone of the ice platform through use of MEDOF brand stress panels placed 6 m from the moonpool. The development of equipment and theories relative to this type of stress field measurement, was judged to be of importance since, in order to achieve a better Arctic engineering design basis, more understanding should be gained on the ice material which dominates the environment. The measured radial stress was low at no more than 100 kPa. It appeared that the presence of the moonpool and warm rig area allowed rapid stress relaxation in this direction. The tangential stress values were broken into two categories - those which occurred before spud date and after spud date. The 180 kPa measured tangential stress before spud date was judged to be accurate. The 750 kPa value recorded after spud date was judged to be a local stress generated around the panel due to a mismatch of panel and ice elastic modulus. The 180 kPa value was well within the 500 kPa limit for platform design limitations. For future ice platform work panels of effective modulus 1270 MPa were recommended.

The platform deflection was recorded at .502 m which is 9% lower than the predicted value of .550 m.

The bladder farm monitoring program allowed for the early detection of a bladder leak and a successful cleanup. On February 14, 1983, the raised snow pad underneath the bladders made a small leak visible. The loader removed the contaminated snow to where it was melted and the fuel burned off.

tti GEOTECHnical resources ltd.
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: June 13, 1984

Panarctic Proposal for 1984-85 Ice Platforms

Discussion document – A study of new methods to accelerate freezing of sea water in nozzle sprays.

This report summarizes the results of a field assessment of the factors which influence the freezing dynamics of a sea water spray.

The spraying of sea water is a common method employed in cold regions such as the Canadian Arctic to construct ice structures which are a necessary part of an offshore oil and gas drilling system. The structures are used to support the drilling equipment and in some instances to prevent disruption of the drilling equipment by mobile sea ice.

Included is a brief summary of the Buckingham B-69 ice platform construction and performance. High pressure pumps were used at this site to enhance freezing. This was accomplished by providing a higher pressure at the nozzle, resulting in smaller water drops travelling a greater distance with resultant beneficial heat loss to the atmosphere (ref.1). A full account will be given in the project report to Panarctic.

Laboratory tests were carried out in Calgary and analysis was conducted in Salt Lake City and in Calgary. The objective was to identify methods that could be applied in the field to accelerate the rate of ice production from a sea water spray. The tests compliment and allow even further optimization of the techniques tried during the B-69 platform construction.

The various elements which comprised these studies included a laboratory evaluation of water soluble chemical agents having the ability to significantly alter the freezing mechanism of sea water. Laboratory results, suggested that the injection of certain chemicals would accelerate the rate at which droplets freeze by virtue of improved heat exchange with the air. The freezing point of a salt solution is depressed relative to deionized water owing to the effect of the dissolved salts. It was hypothesized that use of an effective ice nucleation agent might overcome the freezing point depression effect of dissolved salts in sea water resulting in a solution with a high freezing point relative to the untreated water.

A field evaluation of spray nozzle parameters, chemical injection and compressed air injection on the freezing rate of a sea water spray was carried out at the PANARCTIC OILS LTD., Buckingham ice platform, located at 77 08' 02.8" N latitude, 91 25' 29.2" W longitude, from April 18, 1984 to April 26, 1984. This effort demonstrated the efficacy of chemical injection on accelerating freezing rates of a sea water spray. Typical spray procedures for the spraying of sea water were developed. The new procedures include the use of mobile spraying skids and improved nozzles. Preliminary air injection studies indicated the need for modified equipment. Droplet breakup by air injection will require the use of air dryers to eliminate freezing problems at the air injector ports.

The field experiments were conducted at a time when the ambient air temperature was relatively warm. The rather significant effects of chemical treatment of sea water at these temperatures is extremely encouraging. Field procedures for treatment of sea water with chemicals are straight forward and can be implemented without serious difficulties.

Sandwell

FMS ENGINEERS / LAVALIN
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: September, 1984 (Final)

Offshore Drilling Ice Platform Cisco M-22

Overview:

The Cisco M-22 well was the third offshore well drilled with Rig C. The previous two wells were Cape Mamen F-24 and Grenadier A-26. The wellsite for the main pad was located in relatively thick multi-year ice. This provided for a comparatively short construction period of approximately 5-1/2 weeks.

Construction/Drilling Schedule:

Start Flooding:	**Nov. 27, 1983**
Complete Flooding:	**Jan. 03, 1984**
Initial Thickness:	**5.47 m**
Final Thickness:	**7.02 m**
Start of Rig-up:	**Jan. 04, 1984**
Spud Date:	**Jan. 22, 1984**
Release Date:	**Apr. 12, 1984**

This report presents field data collected, studies platform performance and gives recommendations.

Sandwell

FENCO CONSULTANTS LTD. / LAVALIN
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: SEPTEMBER, 1984

Offshore Drilling Ice Platform Skate C-59

Overview:

The Skate C-59 well is the seventh offshore well drilled with Rig B. The presence of thick multi-year ice allowed for a relaxed construction program of low priority. The initial thickness exceeded the 6.3 m minimum design thickness by 0.25 m. Thus, the aims of the construction program were merely to thicken the thin areas and level the pad.

SITE	START FLOODING	COMPLETE FLOODING	INITIAL THICKNESS	FINAL THICKNESS	START OF RIG-UP	SPUD DATE	RELEASE DATE
Skate C-59	Dec.5	Dec.22	6.55 m	7.32 m	Dec.30	Jan.15	Apr.12

<u>Platform Design</u>

The design criteria are:

1. That stresses from the total of short and long-term loads be limited to 500 kPa.

2. That long-term deflections be limited to the available freeboard.

<u>Platform Loading</u>

The 90 day long-term load was 1340 tonnes, consisting of 928 tonnes dead weight and 412 tonnes variable load. Short-term dynamic loads, if applied simultaneously, would total 487 tonnes. The maximum possible total load is 1827 tonnes.

FENCO CONSULTANTS LTD. / LAVALIN
CLIENT: PANARCTIC OILS LTD.
REPORT DATE: SEPTEMBER, 1984

Offshore Drilling Ice Platform Skate C-59

CONCLUSIONS AND RECOMMENDATIONS

The 920 loader flooded the main pad with one half the effectiveness of the conventional pump system, and at the cost of more man-hours.

The strengths and temperatures of the main ice platform were excellent because of the thick multi-year ice conditions, the double layer of purlboard insulation and an effective moonpool cooling system.

The quality of the airstrip ice was excellent.

The diesel fuel spill of December 14, 1983, indicates that extra care must be taken to ensure that all valves are completely closed.

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CLIENT: PANARCTIC OILS LTD.
REPORT DATE: November 20, 1984

Offshore Drilling Ice Platform Buckingham O-68

1.0 INTRODUCTION

1.1 MAIN PROJECT EVENTS

GEOTECH was retained to design, construct and monitor the ice platform constructed to support Panarctic's Rig A during the 1983/84 drilling program in the high Arctic. The construction, data acquisition and platform performance evaluation for this program forms the basis for this report.

The dates of the main events for the construction program are presented in Table 1.1.1 while Table 1.1.2 features the highlights of the drilling phase of the operation.

TABLE 1.1.1 HIGHLIGHTS - CONSTRUCTION PHASE

	Flooding Started	Flooding Completed	Initial Thickness mm	Final Thickness mm	Build up Rate mm/day
PAD A	**Dec 4/83**	**Jan 29/84**	**980**	**6900**	**104**
PAD 4	**Dec 8/83**	**Feb 15/84**	**1030**	**5460**	**85**
Otter Strip	Nov 25/83	Nov 26/83	900 to 1350	–	–
Herc Strip	Dec 1/83	Dec 26/84	1000	1530	21

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Offshore Drilling Ice Platform Buckingham O-68

TABLE 1.1.2 HIGHLIGHTS - DRILLING PHASE

	Start Rig-up	Rig up Completed	Spud	Rig Release
0-68	Jan 30/84	Feb 16/84	Feb 17/84	May 4/84

The Otter strip was operational on November 26, 1983

The Herc strip was approved for Hercules landings December 26, 1983 and was approved for Boeing 727's on January 13, 1984.

1.2 SITE LOCATION

Panarctic et al Buckingham 0-68, site of Rig A 1983/84 drilling operations, was located offshore Buckingham Island which lies to the South West of Graham Island (refer to Figure 1.2.1). The site coordinates are 77° 08' 00.190" north latitude and 91° 23' 55.263" west longitude. Appendix A includes a detailed site plan, showing location of the main and relief platforms, rig and construction camps, along with the Herc strip.

GEOTECH personnel arrived on site November 27, 1984 where they remained until May 13, 1984.

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CLIENT: PANARCTIC OILS LTD.
REPORT DATE: December 28, 1984

Creep and Relaxation Behaviour of Ice Platforms

Overview:

A study to optimize platform thickness. Based on review of historical platform performance, existing design thickness specifications for Panarctic's conventionally flooded ice platforms are conservative. Platform thickness, loading, ninety-day deflection and initial freeboard is presented for various platforms used in support of Panarctic's drilling operations from 1979 to 1983. The ratio of ninety-day deflection to initial freeboard is plotted against the ratio of platform thickness provided to the existing minimum required thickness. The data was subjected to a regression analysis.

Based on existing minimum thickness requirements and a review of this data, it indicated that the available freeboard at the end of drilling operations, for all these platforms, was in excess of 40% of the initial freeboard. Coupled with the fact that all platforms were in primary creep, this showed that existing design thickness specifications would be improved.

The statistical evidence supports a case for the reduction of ice thickness below minimum requirements presently used. However the extrapolation of the regression curve below $h/h_{min} < 1$ would have no basis in present design.

In order to establish and quantify the deflection and stress behaviour of conventionally flooded ice platforms, in the range $h/h_{min} < 1$, on an engineered basis, required finding a suitable viscoelastic platform model. The model had to be of sufficient complexity to describe the actual behaviour of ice plat forms while not depending on sophisticated and costly computer techniques for their solution.

A viscoelastic floating beam model, which with appropriate modifications, was found to be representative of the long and short term behaviour of ice platforms. The model had the added advantage of being suitable for programming on a desktop calculator.

This report describes the theoretical development of this model as applied to floating ice beams. The modifications and a development of a design procedure for ice platforms, based on the floating beam model, is also described. The design procedure is then applied to the optimum thickness design of Panarctic's Platforms A, B and C.

Recommendations, based on this design, for future platform thickness specifications are also presented for conventionally flooded platforms.

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REPORT DATE: December, 1985

Thermal Analysis Sprayed Ice Platform

Overview:

During drilling of the Cape Allison C-47 well the rig derrick was found to be out of plumb and had to be relevelled several times. After rig out, a depression of the ice surface under the rig matts was noticed. This area was carefully surveyed and contours plotted.

The total ice lateral deflection between the moonpool and mud tanks was 90% of the available freeboard. This was the point of largest deflection and was unacceptably high. It was determined that considerable heat had been supplied to this area of the ice platform by rig matt washing and heater ducts.

The problem experienced can largely be avoided by implementing operating procedures outlined in the report. As well, GEOTECH will carry out extra monitoring during drilling of both temperatures and local deflections.

The principal solution recommended by GEOTECH to deal with the local deflection problem consists of identifying the concentrated heat sources, then making simple modifications to these heat sources and to rig operations to minimize the heat transfer from the rig floor to the ice pad. Specifically this would be the following:

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Thermal Analysis Sprayed Ice Platform

1) Insulation of the end of the duct from no. 1 Tioga heater as well as insulating the sub structure beam area.
2) Modify the baffles of the end of no. 1 Tioga heater duct such that hot air is not blown directly onto the rig floor.
3) Raise the flexible heat duct and provide an insulated pad at the end of this duct such that air is not blown directly onto the rig floor.
4) Minimize washing of the rig matts. Any water used to clean matts should be collected using portable pumps - which is a normal procedure on most rigs. It is vital to minimize the amount of water on the rig matts since much of this eventually reaches the ice surface.
5) Pump excess water out of the spaces between the rig matts. Water should not be allowed to stay on the rig floor or between the matts. This can be accomplished using an air powered pump.
6) Eliminate, or minimize at least, leaks in steam and water lines.
7) Keep external steam lines off the surface of the ice to minimize any heat transfer to the ice platform.
8) Minimize subsea hydraulic fluid spillage.

During the drilling of the well GEOTECH proposes to carry out certain procedures as well.

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REPORT DATE: December, 1985

Thermal Analysis Sprayed Ice Platform

a) GEOTECH has installed extra thermistors in the ice and will be monitoring these thermistors on a daily basis so that if a problem such as last year is detected, a warning can be given and remedial measures can be implemented.

b) GEOTECH will perform a survey of the sub structure beams and other major load components inside the rig buildings. This level survey will be tied in to the main ice platform survey. Thus local deflections will be monitored with the temperature measurements. They will aid in the identification of any problems occuring locally beneath the rig.

c) GEOTECH will inform the Panarctic foremen of the local deflection progress so that remedial measures can be taken, if required. This information will be reported in a daily report to Panarctic in Calgary.

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REPORT DATE: December 17, 1985

Global and Local Deflections Cape Allison C-47

Overview:

Concerns regarding the deflection, thermal behaviour and strength of the ice in the Cape Allison C-47 platform are addressed herein. Ice platform A at Cape Allison C-47 was built up using spray ice techniques. High pressure 50 hp pumps were used to build 6 metres of ice on top of an initial first year ice layer 1 metre thick.

During the drilling of the well at Cape Allison last year excessive tilt of the rig derrick was experienced with the result that levelling had to be carried out during drilling. It nearly became necessary to jack the whole sub-structure of the rig in order to restore the derrick to a plumb condition. In addition, after the rig was removed and the mats taken up, there was a deep depression in the ice beneath the mats. These problems have been analyzed in considerable depth during the summer and fall and conclusions drawn along with recommendations for future operations.

Vertical global deflection of the ice platform was measured in the traditional way and total deflection during the drilling of the well was found to be acceptable. The curve of deflection vs time is presented in Figure 1. The final deflection at Station K-1 left adequate freeboard for the rig. The total global deflection was 584mm whereas the initial available freeboard was 910mm. The behaviour globally of this platform was similar to the flooded ice platform at East Drake and to other flooded ice platforms.

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REPORT DATE: December 17, 1985

Global and Local Deflections Cape Allison C-47

During the drilling of the well at Allison it was found that the derrick was out of plumb and that corrections had to be made to compensate for this. At the end of drilling when the mats were removed a deep depression in the ice was observed underneath the mats. This depression was surveyed in detail by GEOTECH and the results are shown in Figure 2. The depresssion was largest between the substructure of the rig and the mud tanks, and was about 300mm where the two heaviest loads are. The depression was visible to the eye and the surface of the ice platform was visibly contoured.

The global deflection of 584mm plus the local deflection resulted in a total deflection of 826mm. This is abnormal and is generally not observed on ice platforms of any type whether they are sprayed or flooded. With 826mm of deflection there was only 10% of the original freeboard remaining. The ice platform was very close to a situation where water could well up on the top surface of the ice.

In addition to the problem of losing freeboard it is possible that the ice was in some stage of failure. In structures where such large local deformations occur one is justified in suspecting that a punching failure is developing.

PROCEDURES TO CORRECT THE PROBLEM

The principal solution recommended by GEOTECH to deal with the local deflection problem consists of identifying the concentrated heat sources. Then make simple modifications to these heat sources and to rig operations to minimize the heat transfer from the rig floor to the ice pad. Specifically this would be the following:

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REPORT DATE: December 17, 1985

Global and Local Deflections Cape Allison C-47

1) Insulation of the end of the duct from no. 1 Tioga heater as well as insulating the sub structure beam end area.
2) Modify the baffles of the end of no. 1 Tioga heater duct such that hot air is not blown directly onto the rig floor.
3) Raise the flexible heat duct and provide an insulated pad at the end of this duct such that air is not blown directly onto the rig floor.
4) Minimize washing of the rig mats. Any water used to clean mats should be collected using portable pumps - which is a normal procedure on most rigs. It is vital to minimize the amount of water on the rig mats since much of this eventually reaches the ice surface.
5) Pump excess water out of the spaces between the rig mats. Water should not be allowed to stay on the rig floor or between the mats. This can be accomplished using an air powered pump.
6) Eliminate, or minimize at least, leaks in steam and water lines.
7) Keep external steam lines off the surface of the ice to minimize any heat transfer to the ice platform.
8) Minimize subsea hydraulic fluid spillage.

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REPORT DATE: March 1986

Offshore Drilling Ice Platform Project Report Cape Allison C-47

Overview:

Table of Contents:-

HIGHLIGHTS - CONSTRUCTION PHASE

Events Location	Flooding Started	Flooding Completed	Initial Thickness (mm)	Final Thickness (mm)	Build Up Rate (mm/day)
Pad A	Dec 03/84	Jan 16/85	844	6973	136.3
Pad 4	Dec 11/84	Jan 31/85	854	5130	82.2
Otter Strip	Nov 25/84	Nov 25/84	Leveled		
Herc Strip	Dec 03/84	Dec 20/84	1346	1786	24.4

HIGHLIGHTS - DRILLING PHASE

Start Rig-Up	Rig-Up Completed	Spud	Rig Release
Jan 18	Jan 30	Jan 31	May 08

The Otter Strip was operational on November 25, 1984. The Herc Strip was approved for Hercules landing December 22, 1984 and was approved for Boeing 737's on January 3, 1985.

Offshore Drilling Ice Platform Project Report Cape Allison C-47

Sprayed ice at Cape Allison C-47 had accumulated at a rate of 136 mm/day, an improvement of 11.5% over the 122 mm/day rate achieved at the Buckingham O-68 site during the spray flooding portion of the construction.

The build-up rate improvement is attributable to the superior mechanical performance of the swivel and improved spray flooding techniques. The effectiveness of AFA-6 was not conclusive and it is suggested that it be used in higher concentrations on future platforms.

The main ice platform thickness was 6973 mm which lies within the minimum to maximum range of 6400 mm to 7100 mm respectively. The ratio of ninety day deflection to the initial available freeboard was 55%, essentially the same as Buckingham O-68 at 56%. The ratio of the initial freeboard to the final platform thickness was 13.1% whereas Buckingham O-68 was 14.0%. This indicates the accumulated ice was slightly less porous at Cape Allison. The density of the sprayed ice retrieved from cores is 882 Kg/m^3 which is essentially the same as the 890 Kg/m^3 typical of freeflooded ice.

The ice quality tests performed by the borehole jack indicate a mean confined compressive strength of 9.07 MPa, more than adequate for the loads incurred.

The ease of acquiring data generated by the field measurements would be made less arduous a task and facilitate the data reduction procedure in the office if a computerized data acquisition system were implemented at the ice platform construction site.

The continuation of a field and laboratory monitoring/testing program is necessary. The results of such testing will aid in the evaluation and improvement of spray flooding techniques, additives and platform design.

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REPORT DATE: April 1986

N. Buckingham L-71 Offshore Drilling Ice Platform

SITE LOCATION

N. Buckingham L-71, site of Rig C 1985/86 drilling operations, was located at coordinates 77°, 10', 41.669" N and 91°, 29', 27.650" W, approximately 5 km west of Buckingham Island. It is approximately 5 km northwest of the previous Buckingham 0-68 offshore well.

HIGHLIGHTS - CONSTRUCTION PHASE

Location	Flooding Started	Flooding Completed	Initial Thickness	Final Thickness	Build Up Rate
Pad C	Dec 2/85	Jan 16/86	2846	6362	76.4
Pad A (relief)	Dec 7/85	Feb 5/86	2663	6612	64.7
OTTER STRIP	Nov 26/85	Dec 3/85	multi-year	multi-year	N/A
HERC STRIP	Nov 26/85	Dec 24/85	multi-year	>1.68 m	N/A

HIGHLIGHTS - DRILLING PHASE

Start Rig Up	Spud Date	Rig Release
Jan 17/86	Jan 28/86	April 5/86

The Otter Strip was operational on December 3, 1985. The Herc Strip was approved for Hercules and Boeing 737 aircraft on December 28, 1985 and January 3, 1986 respectively.

RECOMMENDATIONS

A review of the data and information contained within this report, has lead to the following recommendations:

1) Relocation of the ice platform should be considered if the designated position places the moonpool in a low area of the platform.

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REPORT DATE: April 1986

N. Buckingham L-71 Offshore Drilling Ice Platform

2) The wind and temperature regime of a site should be considered as part of the decision to use either the spraying or flooding method for ice platform construction. The final decision should also be delayed until a complete profile of the platform thickness has been completed. This will ensure that the average platform thickness is either above or below the threshold thickness determined for this decision.

3) Steaming and washing of rig structures and matts should be minimized. Water produced from such activities should be immediately pumped away.

4) All rig disposal lines should be installed in such a manner so as to avoid the erosion that occurred at the corelab disposal line this season.

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REPORT DATE: April, 1986

W. Cornwall N-49 Offshore Drilling Ice Platform

Overview:

Table of Contents:

Location	Flooding Started	Flooding Completed	Initial Thickness (mm)	Final Thickness (mm)	Build up Rate (mm/day)
Pad A	Dec 6/85	Jan 25/86	894	7090	121.5
Pad C	Dec 9/85	Mar 4/86	859	6451	65.0
OTTER STRIP	N/A	N/A	890	890	N/A
HERC STRIP	Dec 1/85	Dec 23/85	890	1800	39.6

TABLE 1.1.2

HIGHLIGHTS - DRILLING PHASE

Start Rig Up	Spud Date	Rig Release
Jan 27/86	Feb 12/86	April 4/86

The Otter Strip was immediately operational. The Herc Strip was approved for Hercules on December 28, 1985 and Boeing 737 aircraft on January 3, 1986.

West Cornwall N-49, site of Rig A 1985/86 drilling operations, was located at coordinates 77°, 28', 53.020" N and 97°, 17', 32.296" W, approximately 25 km west of Cornwall Island (see Figure 1.2.1).

RECOMMENDATIONS AND CONCLUSIONS

A review of the material and data contained within this report has led to the following recommendations and conclusions:

1) Berming methods and flood timing can be modified to reduce the time required to complete the final stages of the construction program.

2) Spraying efficiency is not significantly affected by ambient conditions, although the actual build up is affected by temperature and windspeed.

3) Active management of build up material on the platform by utilizing a vehicle dedicated to platform construction will improve build ups.

4) AFA-6 at a concentration of 40 mg/L is beneficial in promoting the freezing of sprayed material. It is recommended for use during warm periods (> -30°C) since excess snow is produced at temperatures below this level. If snow is produced it can be spread over the platform using the means discussed in item 3 above and saturated with water to provide a dense ice.

5) The AFA-6 injection system using a methanol mixture worked well and is recommended for future platforms.

6) Calorimetry testing should be performed on future platforms, using the touchdown pattern method discussed in this report. This will allow further evaluation of the effectiveness of spraying methods and additives, and provide a means for validating the assumptions used to analyze the West Cornwall calorimetry data.

7) The global deflection performance of the West Cornwall platform was well within design limits.

8) Local deflection has been identified as a problem. The following recommendations should alleviate this problem:

a) production of high quality (density) ice in the moonpool area.
b) Good thermal management of rig operations i.e. minimal steaming, removal of waste water, reduction of heat input to the rig floor.
c) Construction of a pre-grade of the platform surface prior to rig up, in order to counteract the local deflection.
d) The platform surface should definitly be surveyed and graded if required prior to rig up.
e) Investigate the possibility of improving derrick levelling methods to adjust for local deflection.

9) Flatjacks cannot be used as pressure panels given the present methods of monitoring flatjack response. A data acquisition system would be required to provide sufficient sampling frequency and accuracy to record the small pressure changes.

However, further analysis of the available data and the development of a model may allow the flatjacks to be used as an in situ creep sensor.

10) Platform surface erosion and deflection can be reduced by limiting steaming activity in the rig, removing waste water from between the matts, immediate repair of steam, water and oil leaks, and eliminating or reducing any other potential heat sources to the ice surface.

11) Thermistor installation and locations should be reviewed. Possibilities include the use of more horizontal banks and fewer vertical banks, improved protection for thermistors installed during construction, and installation during construction to allow proper freezeback.

12) Salinity and density profiling and testing should be continued, as this provides an excellent monitor of ice quality during and after construction.

13) Ice coring and visual logging should also be continued for the reasons given in 12.

14) The compressive strengths determined by the borehole jack for sprayed ice are more than adequate for the loads applied to the platform.

15) Elastic moduli of sprayed ice should not be taken as absolute values but rather as index values, due to the nature of sprayed ice.

16) Flatjacks provide an in situ monitor of ice strengths and elastic moduli (as index values) beneath the rig. Flatjacks should be used in the future for this purpose.

17) The compression/ablation monitoring strips have provided valuable data in regards to the behaviour of the top 1.0 metres of ice. Unfortunately, this is a one time only measurement device. The use of instruments used to monitor soil compression may be suitable for providing a continuous measurement of the platform behaviour throughout the platform profile.

18) Sprayed ice is seen to be of lower quality than flooded ice, but sprayed ice quality is still more than sufficient to meet design and performance criteria.

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CLIENT: PANARCTIC OILS LTD.
REPORT DATE: May 1986

Analysis and Design of Floating Spray Ice Platforms

Overview:

Platform A at Cape Allison C-47 was constructed using spray ice techniques. High pressure 37.3 kW (50 hp) pumps were used to build 6 metres of spray ice on top of an initial first year ice layer 1 metre thick.

Vertical global deflection of the ice platform was measured in the traditional way during the drilling of the well and was found to be acceptable. The global deflection measured at station K-1 was 526 mm whereas the initial available freeboard was 953 mm. The global behaviour of this platform was generally similar to the flooded ice platform at East Drake and to other flooded ice platforms.

However, during the drilling of the well at Cape Allison excessive tilt of the rig derrick was experienced with the result that levelling had to be carried out during drilling. It nearly became necessary to jack the whole substructure of the rig in order to restore the derrick to a plumb condition. After the rig was removed and the matts taken up, a deep local depression in the ice beneath the matts was observed. The depression was greatest, about 280 mm, between the substructure of the rig and the mud tanks.

The global deflection of 526 mm at station K1 plus the local deflection of about 280 mm (between the lowest point and station K1) resulted in a total deflection of 806 mm. This is abnormal and is generally not observed on ice platforms. With 806 mm of deflection, only 15% of the original freeboard remained.

To investigate the cause of this local deflection a thermal analysis was commissioned (GEOTECH, 1985). It was determined that considerable heat had been supplied to this area by rig matt washing, heater ducts and other sources. The analysis concluded that the problem of local deflection can largely be avoided by implementing operating procedures to reduce heat transfer from the rig to the ice platform. Specific recommendations were presented in the thermal analysis report (GEOTECH, 1985).

RECOMMENDATIONS

SPRAY ICE PLATFORM THICKNESS

Given the present level of development of the limit states design of spray ice platforms, no change in the design thickness of 6.8 m can be justified at this time. Further work on a comprehensive deflection model will lead to a rational basis for optimizing the thickness of spray ice platforms. The following section highlights the areas of refinement needed in the overall limit states design method for spray ice platforms, and particularly the aspects related to deflection behaviour.

FURTHER DEVELOPMENT OF LIMIT STATES DESIGN FOR FLOATING SPRAY ICE PLATFORMS

1) The data base on physical and mechanical properties of spray ice must be expanded. This will improve the confidence in design values of material resistances and parameters (S, σ_i, E) necessary for design optimization. Also, using these data the material resistance factor ($\emptyset$) must be refined according to the limit states design guidelines (see Section 5.2.3).

2) Materials testing must also continue on spray ice to improve our understanding and data base on the time-dependent properties of spray ice. Creep coefficients under shear and normal stresses must be determined along with their sensitivity to stress level and temperature.

3) The formulation of a rational, constitutive model for spray ice behaviour and overall ice platform behaviour is needed. This is especially true for flexural stress and deflection (local and long-term). Some advances in this area have been made recently through ongoing, in-house work. The yieldline method of analysis for a three dimensional, hinged plate model is summarized in Appendix C. Ultimately a finite element or finite difference program based on such a model may be the most effective tool for design optimization.

4) In light of the sensitivity of spray ice behaviour to variations in its density and porosity, construction methods and control must be assessed and refined to keep the variability of spray ice within quantifiable bounds. Ice quality criteria (density, porosity, temperature) should also be assessed and adjusted if necessary.

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SANDWELL INC. CLIENT: PANARCTIC OILS LTD. REPORT DATE: November 29, 1994
Drake F-76 Abandonment Floating Ice Platform Design

Overview:

To support the equipment spread provided by Panarctic, an ice thickness of 2.7 m was required to ensure that initial elastic stresses did not exceed the allowable and that creep deflections remained less than the initially available freeboard. Data from past Panarctic ice platforms was also used and also from thinner platforms used in Northern Alberta.

A schedule for construction of the platform was presented as well as a program for monitoring quality and progress during construction and performance during the abandonment operation